CALIFORNIA FISH AND GAME

"CONSERVATION OF WILD LIFE THROUGH EDUCATION"

Volume 28 San Francisco, January, 1942 Number 1

8016

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VOLUME 28 SAN FRANCISCO, JANUARY, 1942 No. 1

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CALIFORNIA FISH AND GAME is a publication devoted to the conservation of wildlife. It is published quarterly by the California Division of Fish and Game. All material for publication should be sent to Richard S. Croker, editor, California Division of Fish and Game, Terminal Island, California.

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THE GENERAL SITUATION AND THE BIOLOGICAL EFFECTS OF THE INTRODUCTION OF ALIEN FISHES INTO CALIFORNIA WATERS[1]

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The introduction of exotic species into any area is an abrupt and artificial extension of a natural process. All animals are continually trying to expand their range. They are constantly pressing against the limits of their habitat, moving outward slowly or swiftly according to their nature from their centers of origin until they meet an impassable barrier. Without the interposition of such barriers all species would eventually be of worldwide distribution.

Man alone is capable of transporting animals across almost any distance and over practically all barriers. What are his reasons for bringing species into areas where they do not naturally exist? Various as they may be, they all have one common objective—to provide him with some form of satisfaction which the indigenous species do not. Utilitarian satisfactions come first to mind but esthetic and sensory satisfactions are also important. Commercial fishes belong in the first category; they provide the necessities of life. Game fishes belong in the second category; they provide pleasure, and without some form of pleasure most men do not find life worth living.

Aside from the two foregoing, a third incentive plays a part in almost all of man's efforts to transplant species—his immense and unquenchable curiosity, his uncontrollable desire to "see if it will work." This phenomenon has manifested itself in waves of varying intensity throughout the history of the subject under discussion, and one of its modes, if not indeed its all-time high, occurred in the last half of the last century. At the same time the exploitation of California was at its zenith, and the pull of these two forces coincided to bring a veritable tidal wave of exotic fishes flowing into the State. In 1874 alone, according to Evermann and Clark (1931), seven different species were brought in, and from 1871 to 1894 at least 25. The total number of attempted introductions given in their paper is 32, and Smith (1896) lists three which they do not include. Of these fishes, four came to us from other continents—the Loch Leven or brown trout, the carp, the goldfish and the tench. The remainder came from our Atlantic seaboard and middle western states.

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[1] This paper was presented at the symposium, "Introduced fishes in waters of the Pacific Coast," at the meetings of the Western Division, American Society of Ichthyologists and Herpetologists, held in Pasadena, California, June 18, 1941.

In this epidemic of transplantations, there seems to have been little realization of the possible attendant dangers. The unfortunate lessons of the rabbit in Australia and the mongoose in Haiti had not yet been learned, and the only effort appears to have been to increase the number of species, to find a place where the exotic would prosper, regardless of the effect.

A great many of these strangers failed to establish themselves. In some cases ignorance of natural history was to blame—some unrecognized condition essential to the completion of the life-history was wanting. No one at present would make repeated attempts to introduce the Atlantic eel to the Pacific Coast, but in 1874 Johannes Schmidt had not yet shown that this eel must get to the Sargasso Sea in order to reproduce. In some cases no unoccupied niche existed to which the exotic was adapted. This may account for the failure of the Atlantic salmon; all suitable waters were so filled and overflowing with Pacific species that there was no room for the newcomer.

Another outstanding failure was the Great Lakes whitefish, *Coregonus clupeaformis*. The desire to establish them in Tulare Lake and in Clear Lake, where a total of 45,000 was planted to no avail in the early 70's, is not incomprehensible. But what they were expected to contribute to Lake Tahoe and Donner Lake, where 250,000 were planted in 1877, is a mystery, in view of the large population of the Rocky Mountain whitefish (*Prosopium williamsoni*) at that time present in those waters.

FIG. 1. Striped bass fishing on San Francisco Bay. The introduced striped bass furnishes sport for many thousands of enthusiastic anglers in central California. San Quentin Point, July, 1938.

Let us turn now to the biological effects of these aliens. By this we mean the effect upon other forms of life already in the region, and it may be said at the start that few transplantations of species have ever actually increased the welfare of the native fauna, however much they may have increased the welfare of human beings. For every introduced species, if it is to establish itself, must either find an empty

ecological niche or shoulder its way into the niche already occupied by some other animal. In the first case it may do no direct harm but may, freed from the natural controls which kept it in check in its own land, overrun the new territory to the detriment of other animals. In the second case, the infringement of the alien upon the native may be considered under two headings:

1. The direct effect, either as predator or competitor.

2. The indirect effects--introduction of parasites; alteration of the habitat; modification of the life-history of the introduced fish or the native.

Obviously the aliens which failed to estabish themselves in our waters had no permanent direct effect. As to their indirect effect, it is conceivable that they might have introduced some parasite before perishing, but no case of this kind has been reported.

That the fishes which did succeed in establishing themselves have all had at least some effect upon the natives is probable. In some cases it has been so trifling as to be negligible; in others the native affected has not been of interest to man; and in others the introduced population is still too small to have had any noticeable influence. The following species, however, seem to demand consideration in detail:

1. The shad (*Alosa sapidissima*). No detrimental effects are reported for this fish, in spite of the great abundance which it has at times attained in the Sacramento River system. It seems to be possible to point to this species as the one case of an introduction which has caused no complaint from any quarter. It has apparently found an ecological niche which was not only completely unoccupied but also large enough to accommodate an enormous population.

2. Striped bass (*Roccus saxatilis*). For many years this was thought to be a purely beneficial introduction, but in 1936 Shapovalov found young salmon and steelhead in striped bass stomachs in the lagoon mouth of Waddell Creek, a small coastal stream in Santa Cruz County. In an effort to throw light on the part played by striped bass in the depletion of salmon, Hatton (1940) examined 224 striped bass stomachs in 1939 in the Sacramento River near Pittsburg when the young salmon were descending to the sea and found not one single identifiable salmon. This is not proof, however, that in the clearer, shallower waters farther up the river the striped bass does not feed on both salmon and trout. The striped bass is known to feed upon the bay smelt.

3. Small-mouthed black bass (*Micropterus dolomieu*) and large-mouthed black bass (*Huro salmoides*): California authorities, aware of the incompatibility of black bass and trout, have endeavored to confine the former to waters unsuitable to the latter. For that reason detrimental effects have been limited. Partly through unauthorized transplantations, black bass have gained access to some trout waters with bad results. Notable is Lake Britton in the Pit River drainage. Conditions here are in many ways excellent for trout, but the large-mouthed bass have taken over the lake, and although they furnish good fishing trout are rarely caught any more. It appears that where conditions are more or less equally suitable to both fish, the bass dominate the trout through greater adaptability, predaciousness, and all-around

hardiness. It is only where conditions definitely favor the trout that it seems able to prevail over the spiny-rayed intruder.

The black bass has been found to feed on down-stream salmon migrants (Hatton, 1940). From its habits it may be guessed that it is at least a competitor with, if not also a predator on, its near relative, the native Sacramento perch (*Archoplites interruptus*).

4. Sunfish. Two species are known to be well established in California, the bluegill (*Lepomis machrochirus*) and the green (*Lepomis cyanellus*). In some parts of the State they are called fresh-water perch. They furnish much excellent minor fishing but their biological

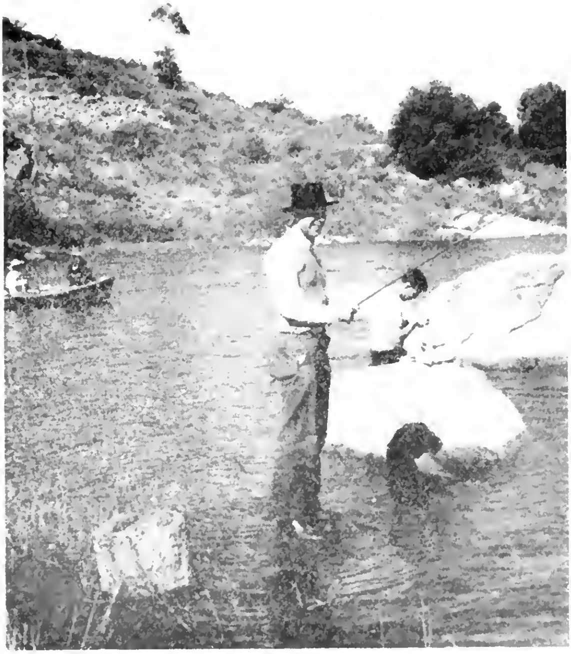

FIG. 2. A typical scene on a southern California lake. Many municipal and private reservoirs and flood control lakes have been stocked with black bass, sunfish and crappie and furnish excellent sport to throngs of fishermen. Lake Wohlford, May, 1939.

effect seems to be largely limited to their relationship with another introduced fish, the black bass, on whose eggs they prey to some extent and for whom their young furnish an abundant food supply.

5. Crappie, white and black (*Pomoxis annularis* and *P. nigromaculatus*). Both species have been introduced. They are known to prey upon the young of the black bass, sometimes to the extent of

greatly decreasing their numbers. They are not known to have detrimental effect upon any of our native fishes of value.

6. Catfish, fork-tail (*Ictalurus catus*) and square-tail (*Ameiurus nebulosus*). These are scavengers and to some extent predators upon the eggs and young of many other fish. They are believed by some people to be responsible for the decrease in number of the native Sacramento perch. They have been introduced to some extent by unauthorized and uninformed persons to high mountain waters, where they become so stunted as to be of no value to man, and where they none the less sometimes become so numerous that they inhibit the trout populations through competition and sheer force of numbers.

7. Carp (*Cyprinus carpio*). This has become the most unpopular fish ever brought into California. It stands as Public Enemy No. 1 on the fisherman's books. It is accused of preying on the spawn of other species, including the Sacramento perch; of making the water it inhabits muddy; of digging up plant life; and of being a general nuisance to fishermen. The last three points are undoubtedly true. In competing with game fish its rapid growth, its high fertility, its adaptiveness and its hardiness give it the advantage. Its young, on the other hand, undoubtedy furnish food for valued fishes. Sentence seems to have been passed upon it for determined efforts are being made to control or eradicate it in all parts of the United States.

8. Loch Leven or brown trout (*Salmo trutta*). There is a feeling among some fishermen that this trout is more cannibalistic than the other members of the genus, but no evidence exists to support the theory. It is true, however, that this species is more difficult to catch than the others, especially in lakes; that, therefore, individuals survive to a greater size and age; and that large trout, regardless of species, are more apt to be fish eaters than small ones through sheer force of necessity, the smaller forms of food being insufficient to sustain them.

As biological credit for this trout must be placed the fact that it lives contentedly in the slower, weedier portions of trout streams not favored by rainbow and thus brings about a more complete realization of the biological potentialities of the habitat.

9. Eastern brook trout (*Salvelinus fontinalis*). Little can be said against this trout on the purely biological side. In its favor—it seems to do well in high mountain lakes with very cold water and short summers, and it is able to spawn more successfully than rainbow trout in spring seepages in the bottoms of such lakes, thus maintaining itself naturally where the rainbow has difficulty. Like the Loch Leven, therefore, it utilizes a portion of the trout habitat which would otherwise be wasted.

10. Mackinaw trout (*Cristivomer namaycush*). This species is a center of controversy. It has reached its greatest abundance in Lake Tahoe where it is now maintaining itself without any artificial aid. Since the practical disappearance of the native cut-throat it has become the mainstay of the Lake Tahoe fishery. Many anglers look upon it as a great asset; many others have no use for it and blame its depredations for the depletion of the native trout. The mackinaw undoubtedly subsists largely on fish. Examinations of several hundred Lake Tahoe mackinaw stomachs over the past three years have

shown remains of many suckers, minnows and sculpins, but only a single identifiable trout. This is not conclusive proof that mackinaw do not prey upon trout but its deep water habits would not tend to bring it into contact with the young of the other trouts in Lake Tahoe, and it is entirely possible that the rise of the mackinaw population, at the same time that the native trout were decreasing in number, is not a case of cause and effect but of coincidence.

FIG. 3. Black bass fishing on Havasu Lake, formed by Parker Dam on the Colorado River between Arizona and California. Introduced fishes, particularly black bass, catfish, sunfish and crappie furnish practically all the fishing in the lakes of Arizona, Nevada and southern California. Photographed January, 1941.

From the foregoing pages it can be seen that the introduced species may be arranged in three general groups by biological effect:

A. Those entirely harmless, at least in so far as we now know, to the native fishes. The only eligibles for this category are the shad and perhaps the sunfish.

B. Those accused—although by no means always convicted—of offenses of varying degrees of importance. The following are ranked in increasing order of criminality, that is, with the least guilty at the top:

Eastern brook trout
Crappie
Loch Leven or brown trout
Mackinaw trout
Striped bass
Black bass
Catfish

C. Criminals of the deepest hue. Some people would include catfish in this group but the only unanimous choice would be the carp.

This grouping appears to emphasize the debit side of the biological ledger, with the threatened extinction of the Sacramento perch the most serious crime on the docket. However, it must be remembered that the evidence is by no means conclusive and that evils of various kinds are blamed on introduced exotics which are really due to quite different causes. Draining of the tule fields and overfishing may have as much to do with depletion of our native perch as alien depredations. Also, it must be remembered that this appraisal has deliberately excluded, because of their assignment to a later place on the program, the compensating circumstances—the increases in human welfare brought about by those same exotics which are accused of decreasing the welfare of our native fishes.

The fact is that Nature left a real scarcity of game fishes in the warmer fresh waters of California. Man has done away with this scarcity. Entirely aside from the catfish, much sought after in some parts of the state, our latest data show that over 35 per cent of all our licensed anglers fish for species which were brought into our waters from outside our boundaries.

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ALIEN FISHES IN THE WATERS OF THE PACIFIC NORTHWEST[1]

By WILBERT MCLEOD CHAPMAN
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The present report is a list of the species of fishes which have been introduced into the fresh and marine waters of the Pacific Northwest, the history of their introduction where known, the manner in which each species has been acclimated in the new habitat, the present distribution as far as known, and the relative importance of the various species in the sport and commercial fish catches at the present time. The data for British Columbia are fragmentary and are not intended to be complete. Such data as are available have been furnished by Dr. Ferris Neave, Fisheries Board of Canada, and Dr. W. A. Clemens, University of British Columbia. The Province of British Columbia has regulations against the introduction and dispersion of spiny-rayed fishes. The data for Oregon are felt to be complete as far as known for the presence of the various species, but information on the relative abundance and dispersion within the State is fragmentary.

Through the kindness of Mr. Clarence Pautzke, Chief Biologist, Washington Department of Game, the statistics of the game catch of fish in Washington have been made available and most of the notes on the present distribution of alien game fish in Washington are traceable to him. Because of the active research of Pautzke and his associates in recent years, the notes on the alien fishes in Washington are felt to be fairly complete, although it will probably be found when the fish fauna of Washington becomes fully known, that other species of centrarchid fishes than those mentioned will be found. The figures which are cited on the relative abundance of the various species in the sport catch of Washington are taken from the state-wide creel census of the Washington Department of Game. Since this census is more complete for the lake fisheries than the stream fisheries and does not include the considerable marine sport fisheries of the State, the figures are skewed to the lake-dwelling species in an amount not known.

What little is known of the history of the introduction of the various species in the northwest is taken from H. M. Smith's (1896) report. Until 1933 the game fishes of the State of Washington were under the regulation of county game commissions. Little is known of the activities of these independently operated bodies. The policy on introducing new fishes varied from county to county and was undertaken by the county commissions, the United States Bureau of Fisheries, sportsmens' organizations, and often independently interested sportsmen.

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[1] This paper was presented at the symposium, "Introduced fishes in waters of the Pacific Coast," at the meetings of the Western Division, American Society of Ichthyologists and Herpetologists, held in Pasadena, California, June 18, 1941.

At least 25 species of fish have been introduced, more or less successfully, into the waters of Oregon, Washington and British Columbia, as follows:

1. ***Alosa sapidissima,* Shad:** The shad was introduced into the Sacramento River as early as 1871 (Smith, 1896) and was first definitely recorded from the Columbia River in 1880 (Jordan, 1916). In 1885 shad fry were planted in the Snake River near its entrance into the Columbia and in the Willamette River at Portland, Oregon. In 1896 plants were made in the Willamette at Albany, Oregon, and in the Columbia at Wallula Junction, Washington. A total of 910,000 fry was planted in these two years, and so far as is known these were the only plantings of shad in the Northwest.

At present shad have been recorded from Coos Bay, Rogue River and Yaquina Bay in Oregon; they support a commercial fishery in the Columbia River; they have been taken this year in the pilchard purse seines on the Washington coast between Destruction Island and Umatilla Lightship; they are taken occasionally in Willapa Bay, Grays Harbor, lower and upper Puget Sound in Washington and in the Fraser River, British Columbia. They have been recorded from Rivers Inlet, British Columbia, Stikine River, Alaska (Smith, 1896), and Kodiak Island, Alaska (Welander, 1940).

The first report of shad being taken commercially in the Columbia is that of the United States Commission of Fish and Fisheries (1892), in which is noted that in 1888 there was a total catch of 10,000 pounds valued at $500. The shad fishery was badly neglected for many years because of the cheap price of the fish and the abundance of the more preferred salmon. Immense quantities were destroyed incidental to the salmon fishery. At present the catch is increasing yearly. On the Washington side alone there were taken: in 1937 a total of 37,606 pounds; 1938, 52,734 pounds; 1939, 86,984 pounds; and in 1940, 111,103 pounds. The total catch of both Oregon and Washington was 171,300 pounds in 1938 and 351,318 pounds in 1939. Nowhere else in the Northwest does the species support a commercial fishery.

2. ***Salmo clarkii lewisi,* Montana Black-Spotted Trout:** This subspecies of cut-throat trout has been widely planted in lakes all over Washington and has established itself in many of them. The stock came from Montana and Yellowstone Lake. It apparently does best in the higher lakes and in the more alkaline lakes of eastern Washington. It is not segregated from other species of trout in the records of game fish catches in Washington.

3. ***Salmo trutta,* Brown Trout:** The brown trout has been widely planted in the lakes and streams of Oregon and Washington. It has done well only in restricted localities. It has been recorded from Baker Lake and Big White Salmon River, Washington; Clackamas River and Sucker Lake, Oregon. In Washington it maintains itself in abundance only in certain warm lakes (such as Slide Lake) in Klickitat and Yakima counties. It is found in the Natches River, Deep Lake, King Lake, etc., but is not thought to reproduce naturally in these localities. In British Columbia it has been introduced and has established itself, although not in abundance, on Vancouver Island in

the Cowichan River system. In Oregon it is said to have established itself in the upper reaches of the Deschutes drainage.

4. ***Salmo salar*, Atlantic Salmon:** An attempt was made to introduce this species in the Cowichan River, Vancouver Island, British Columbia, but the attempt was unsuccessful.

5. ***Cristivomer namaycush*, Mackinaw or Lake Trout:** This species has been widely introduced into the lakes of both eastern and western Washington. Although taken but rarely in the lakes of western Washington, it is firmly established and abundant in certain lakes in Pend Oreille, Ferry and Spokane counties in northeastern Washington; and in these lakes it forms a valuable game fish resource.

6. ***Salvelinus fontinalis*, Eastern Brook Trout:** This species has been introduced widely throughout Washington, Oregon, interior British Columbia and in the Cowichan River system on Vancouver Island. As many as 20,000,000 eggs per year have been imported into the State of Washington alone in recent years. In 1938, 8.0 per cent of the sport fish catch checked by the Washington Department of Game consisted of eastern brook trout, and in 1939, 14.1 per cent. Although common throughout Washington, it reproduces abundantly only in rather restricted localities, in particular such streams as the Spokane River and lakes of Okanogan, Chelan and Kittitas counties. As a result of recent research the Washington Department of Game has been able to concentrate its plantings of eastern brook trout in those localities where it thrives and reproduces itself naturally. As a consequence, although the areas of planting have been restricted, the total abundance of the species is increasing.

7. ***Salmo agua-bonita*, Golden Trout:** This species was introduced by the United States Forest Service in three or four small, high mountain lakes of the Skykomish River drainage in northwestern Washington in 1936. The species has thrived, is reproducing naturally, and is now producing a sport catch in these formerly barren lakes.

8. ***Coregonus clupeiformis*, Common Whitefish:** In 1889 this species was planted by the United States Bureau of Fisheries in Klamath Lake, Kullaby Lake, Chetaw Lake and Laddis Lake in Oregon and in Lake Washington, LaCamas Lake and Silver Lake in Washington. In addition plants were made in the Columbia River drainage in Idaho at Coeur d'Alene Lake, Pend Oreille Lake and Hayden Lake. So far as known none of these plants was successful. I have been told by hatchery men, in whom I have some confidence, that very large whitefish had been taken in past years in lakes Sammamish and Washington and a possibility exists that the original plants lived but did not reproduce.

9. ***Cyprinus carpio*, Common Carp:** So far as is known this species was first introduced into Idaho, Oregon and Washington by the United

States Bureau of Fisheries in 1882 (Smith, 1896) and there were many subsequent introductions. It is at present one of the most widespread fishes of the Northwest. It occurs everywhere that it can get to or has been taken. In the Columbia River it is very abundant in the sloughs and inlets of the lower river and is more or less abundant in all its tributaries, even up into British Columbia. There is a small commercial fishery on the Washington side of the Columbia centering on Lake Vancouver. In 1937, 126,705 pounds were produced; in 1938, 90,785 pounds; and in 1939, 104,487. Although the species can usually be found in the Seattle and Portland markets, its use as food is restricted to certain national groups and it is noted as at least a mild pest rather than as a food fish. In some of the alkaline lakes of eastern Washington, such as Moses Lake, the abundance is tremendous. In Moses Lake a small commercial fishery exists whose product is dried carp meal, which is sold for fish food.

10. *Tinca tinca*, **Green or Golden Tench:** The first known introduction of tench into the Northwest was plantings made by the United States Bureau of Fisheries in small lakes of Spokane County, Washington, and Washington County, Oregon, in 1895 (Smith, 1896). It is now found in the Columbia River, in certain streams and lakes of the Puget Sound drainage (especially Lake Washington and communicating lakes), and on Vancouver Island. In some places, particularly lakes in northeastern Washington, it is fairly abundant, but it is nowhere as abundant nor is it as widespread in occurrence as its relative, the carp. In eastern Washington it is fished to a slight extent as a sport fish, but it is not highly regarded and is generally ignored by sportsmen.

11. *Carassius auratus*, **Goldfish:** In the mild climate of western Washington it is possible to raise goldfish in outdoor ponds and those found in the wild state are probably domestic pets which have escaped, or fish which were used for bass bait and escaped. The goldfish has been taken in the Columbia River at its mouth and at Kalama. It has apparently become established in Lake Washington in western Washington and Moses Lake in eastern Washington, but it is not common anywhere.

12. *Ameiurus nebulosus*, **Catfish:** When the catfish was introduced into the Northwest is not a matter of record. It was recorded from Silver Lake, Cowlitz County, as early as 1888 (Smith, 1896). It is widespread in the lakes and streams of Oregon and Washington on both sides of the mountains, and is especially abundant in the sloughs and slack water of the lower Columbia. It is also found in several lakes on Vancouver Island and in Shawnigan Lake, British Columbia. Its abundance is not well reflected in the sport catch because the sedentary nature of the method of fishing for them is not to the liking of people accustomed to trout and salmon fishing. Nevertheless, in 1938, 2.5 per cent of the recorded catch of game fish in Washington was catfish, and in 1939, 2.3 per cent. There is no commercial fishery in the Pacific Northwest.

13. *Ameiurus melas*, **Black Catfish:** This species has been recorded from the Columbia (Smith, 1896) but has not otherwise been noted in

the literature. It is quite possible that this species is more common than realized and is confused with the more common *nebulosus*.

14. *Esox lucius*, Pike: It is recorded (Smith, 1896) that the U. S. Fish Commission made a planting of pike near Boise, Idaho, in 1892. No specimens have ever been recorded from the Northwest.

15. *Esox vermiculatus*, Pickerel: There is no record of the introduction of the pickerel. It is found in the streams of southeastern Washington, chiefly in the Snake and Walla Walla drainages and in some lakes near Spokane. It is not abundant, does not reach a large size, and there is no record of its occurrence elsewhere in the State. It is possible that this species resulted from the above noted planting of *E. lucius* which was made farther upstream in the Snake and that the species planted was misidentified.

16. *Perca flavescens*, Yellow Perch: In 1890, 1891 and 1892 (Smith, 1896) perch were planted in Loon Lake and Lake Colville near Spokane, in the South Palouse River, in Lake St. Clair near Tacoma, and in Silver Lake, Cowlitz County, in Washington. Subsequent introductions and distribution between different county game commissions and sportsmen's clubs have probably been plentiful. It is now present in practically all lowland lakes of Washington and Oregon. Aside from the land-locked sockeye, or silver trout, it is the most abundant fish in the creels of the Washington sportsmen. In 1938 and 1939 it made up 22.5 per cent of all the fish in the creel census of the Washington Department of Game. The combined statistics of the lake fisheries of King County showed in 1937, 37 per cent cutthroat trout, 33 per cent perch, 18 per cent rainbow trout and the remaining 12 per cent were steelhead, eastern brook, silver trout, crappie and small-mouthed bass. Some lakes are tremendously productive. In Fish Lake, Chelan County, about one-third of the sportsmen's catches are recorded. This is a small, shallow body of water about three-quarters of a mile long. In 1938, the 2,631 fishermen checked had 30,610 perch; in 1939, 2,768 fishermen checked had 40,925. In that year, the lake must have produced something like 120,000 perch. Other species are less plentiful in the lake. In 1940 partial statistics showed 24,094 perch, 54 crappie, 25 catfish, 22 large-mouthed bass, 19 small-mouthed bass, 2 silver trout, 1 rainbow trout and 1 sunfish. Silver Lake, Cowlitz County, is famous as a bass lake but 1938 checks of the Department of Game showed that the sportsman's creel contained 42 per cent perch, 30 per cent catfish, 16 per cent crappie, 14 per cent large-mouthed bass, 1.5 per cent cutthroat trout, and 1.5 per cent sunfish. The perch is the family sportsmen's fish. Everybody can catch them. They are not highly regarded as are the trout, salmon and bass but they are much more widely caught than those species. In a number of small pot-hole lakes in King County where no one used to fish, the Department of Game introduced rainbow trout with great success. People now swarm to the lakes to catch rainbow and come home happily with a creel full of perch, for which they would not bother to fish before, and a couple of trout.

17. *Huro salmoides,* Large-mouthed Black Bass; and 18. *Micropterus dolomieu,* Small-mouthed Black Bass: In 1890, 1891, 1893 and 1895 (Smith, 1896) and probably in many subsequent years, bass were planted widely in Oregon and Washington by the United States Bureau of Fisheries and they have since been spread even more. They support a valuable sport fishery in the lowland lakes of both states and in the backwaters of the lower Columbia River. Their abundance is apparently limited by the lack of native minnows in quantity for food and the relatively small number of lakes suitable for bass.

19. *Chaenobryttus gulosus,* Warmouth Bass: This species has been taken at Kalama on the Columbia River (Chapman and DeLacy, 1933) but is not recorded elsewhere in the Northwest. They were introduced in Loon Lake, Washington, and in the Boise River, Idaho, 1892 (Smith, 1896) but have not since been recorded from these localities.

20. *Helioperca incisor,* Bluegill Sunfish: This species has been taken at Kalama on the Columbia River (Chapman and DeLacy, 1933). Although it has not been recorded from elsewhere, it is probably more widespread. It is quite possible that other Centrarchidae, accidentally introduced, will be found in the Northwest, especially in the sloughs of the lower Columbia River. There has been little scientific collecting done there, and the species of Centrarchidae in this region are much confused by the fishermen, to whom they are either sunfish or crappie.

21. *Lepomis cyanellus,* Green Sunfish: Doubtfully recorded from southern Oregon.

22. *Lepomis gibbosus,* Pumpkinseed Sunfish: Common in the Puget Sound drainage, Columbia River drainage, Goose Lake, Oregon drainage, and elsewhere in the lowland lakes of Oregon and Washington on both sides of the mountains. In many of the small lakes of King County the pumpkinseeds are very abundant but never become more than a few inches long. It is characteristic of the species in western Washington to remain small. In Kahlotus Lake in Franklin County, Washington, however, the species reaches as much as $1\frac{1}{2}$ pounds in weight. They comprise about 0.8 per cent of the sport catch recorded by the Washington State Department of Game.

23. *Pomoxis annularis,* White Crappie; and 24. *Pomoxis nigromaculatus,* Black Crappie: The two species of crappie were planted in lakes near Spokane in 1890 and 1892 (Smith, 1896), but since then must have been planted widely in both Oregon and Washington because they are at present widespread in the lowland lakes of both states on both sides of the mountains. They are also abundant in the lower Columbia, lower Willamette and in other smaller, slow moving streams in both states. The two species are confused by the sportsmen and in the catches. They form a little more than 4 per cent of the total sport catch recorded by the Washington Department of Game and thus take sixth place in relative abundance in the sportsman's creel, well ahead of bass, catfish, Dolly Varden trout, whitefish, etc.

25. *Roccus saxatilis*, Striped Bass: Although the striped bass were introduced into San Francisco Bay as early as 1879, there is no record of them ever being introduced into the Northwest. They have spread up the coast as far as southern or central Oregon, however, and are fairly abundant in Coos Bay. Fiedler (1941) gives the commerical catch of striped bass in Oregon in 1938 as 44,100 pounds valued at $2,192. Stanley Jewett, Columbia River Pollution Commission, advises me that one specimen has been taken from the Columbia River at The Dalles, Oregon, and two or three specimens have been taken at the mouth near Astoria. There is no record of their capture in Washington.

The above list does not take into consideration the numerous and extensive transplantations of foreign stocks of native species which have taken place in the past and are being carried on at present. Instances of this were the importation of even-year pink salmon from Alaska into Puget Sound, where this species runs only on odd years, and the heavy importation of rapidly growing, deep-bodied rainbow trout from Idaho and Wisconsin, where the form has been developed, into Washington, where the species is native.

Of the 25 species, 21 have succeeded in establishing themselves and are more or less abundant. One, the shad, is fairly important in the commercial fishery of the Columbia River and two others, the carp and striped bass, support small commercial fisheries. It is as game fish, however, that the introduced species have become of greatest importance. In a state such as Washington, which is famous for its trout and salmon fishing, it is interesting to note that of the fresh-water game fish catches recorded by the Department of Game in 1938 and 1939, 44 per cent were of introduced species. No matter what one's opinion of the introduction of spiny-rayed fishes into salmon and trout waters, or of the great nuisance that carp can become, it is clear that the introduced fishes have come to occupy an important place in the fish fauna of the Northwest.

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ECONOMIC APPRAISAL OF INTRODUCED FISHES IN THE WATERS OF CALIFORNIA [1]

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The fish introduced into California waters have been of immense economic benefit to the people of the State and have afforded fresh-water anglers much pleasure. In fact, angling for the species which have been introduced into California is equally as important as the fishing for all of the native fresh-water and anadromous fishes. Consequently, the introduction of these foreign species has doubled the amount of fish that may be taken by sportsmen. Some of these introduced species have attained commercial importance, although they have contributed only a minor part to California's very large commercial fishery.

Some harm may have been done to native species by these introductions, but there is no evidence that the damage has been extensive. Perhaps carp should be classed as harmful for they are generally considered a nuisance. However, taken as a whole, it would seem that the introductions were a good investment. The cost was only a few thousand dollars and from all available information the returns have been worth many millions of dollars.

A literal definition of "economic appraisal" as it pertains to fishery resources is understood to mean the potential value, based upon the income derived from the fishery resources over a period of years, plus the annual income from the fishery. The actual valuation of a fishery in all its aspects has always been a difficult problem and one which has occasioned considerable dispute in recent years.

In the economic appraisal of the introduced species which are or have been fished commercially, the procedure is as follows, in order to show two totals of potential value and annual value.

1. An appraisal of the potential value of the basic stock calculated on the basis that the fisheries will yield, if well managed, an annual return in poundage and dollars over at least a 50-year period. (Fifty years are used to compare with the length of usefulness of many water uses such as dams and irrigation systems.)

2. The average annual amounts paid to fishermen, based on recorded market prices, plus a 33 per cent increase over fishermen's value to cover the wholesale costs, plus a 50 per cent increase over wholesale values to account for retail worth.

3. To the preceding item is added an estimated value of allied industries or capital improvements necessary to carry on the fishery.

[1] This paper was presented at the symposium, "Introduced fishes in waters of the Pacific Coast," at the meetings of the Western Division, American Society of Ichthyologists and Herpetologists, held in Pasadena, California, June 18, 1941.

These include gasoline and oil; boats and boat repairs, replacement and depreciation; construction, repair and improvement of plants; and the acquisition and maintenance of fishing gear– all based on the size of each commercial fishery.

The appraisal of the introduced species which are taken by anglers is a much more difficult task than the determination of the value for a species taken commercially. Basically, the value of the sport fishery is entirely commercial for there is value or gain to many types of business as a result of the sport of angling. Tackle dealers, boat renters, small motor dealers, sport clothing manufacturers, gasoline companies, hotels, tourist camps, restaurants and resorts, all do a large amount of business with sport fishermen.

The U. S. Chamber of Commerce together with the U. S. Fish and Wildlife Service have estimated from statistics gathered from all of the States that an average of $87 per year is spent on fishing by each holder of a fishing license. On that basis the entire sport catch of fish in California in 1938, during which 346,661 angling licenses were sold, had a commercial value of approximately $30,160,000. This figure may be compared to the value of the commercial fisheries in California for the same period of approximately $75,000,000.

FIG. 4. Shad fishing on Suisun Bay. In recent years shad fishermen have received approximately $50,000 annually for their catches. The retail value of the fish is several times this figure. As the California shad fishery has been carried on for about sixty years, the small original cost of introducing the fish to our waters has proved to be a good investment. Photograph by H. B. Nidever, April 21, 1936.

Based on the calculated numbers (26,068,000) of sport fish taken in the State from the analysis of Brian Curtis (manuscript) on the reported sport catch for 1938, the value per fish would be $1.15.

This figure seems excessive for some species of fish, such as striped bass and catfish, which are easily accessible to a large fishing population. On the other hand, trout, salmon and perhaps black bass might be valued higher than the average. It may be noted here that it is obviously impossible to even estimate the value to the anglers of the physical and recreational benefits derived from fishing.

The procedure used in the appraisal of the introduced species taken by anglers is as follows, to show both potential value as well as today's annual value:

1. An appraisal of the potential value of the stock as a whole of noncommercial species, based on the assumption that the annual yield to anglers will continue for a 50-year period.

2. The total average annual cost of fish to sport fishermen in terms of money spent on fishing trips and fishing equipment.

Some of the introduced species in California are both sport and commercial fish. The economic appraisal of these species has been arranged in the following table:

	1 Potential value of the fishery over 50-year period	2 Annual commercial value of the fishery	3 Allied industry* value	Combined value of commercial and allied industry (Columns 2 and 3)
Shad	$6,727,500	$134,550	$810,000	$944,550
Striped Bass:				
Sport	113,275,000	2,265,500	------	2,265,500
Commercial	400,000	8,000	10,000	18,000
Total	113,675,000	2,273,500	10,000	2,283,500
Catfish:				
Sport	200,100,000	4,002,000	------	4,002,000
Commercial	3,667,500	73,350	20,000	93,350
Total	203,767,500	4,075,350	20,000	4,095,350
Carp	370,500	7,410	5,000	12,410
Spiny-rayed Fishes	172,500,000	3,450,000	------	3,450,000
Trout	154,330,000	3,086,600	------	3,086,600
Grand Totals	$651,370,500	$13,027,410	$845,000	$13,872,410

* Allied industry value for shad includes much of the capital improvements which are used also by commercial catfish and striped bass fishermen.

Shad are taken almost entirely for commercial use. A very limited amount is taken by sportsmen. On the other hand, striped bass have been confined to an angler's catch in California since 1935. About 50,000 pounds a year have been caught as an incidental catch to shad, but after 1941, it will be illegal to sell such catches. The calculated anglers' catch of striped bass in 1938 was 1,970,000 fish, or 21 fish to each angler.

Catfish are taken by both commercial and sport fishermen. The commercial landings average about 300,000 pounds a year, or approximately 600,000 fish. A tremendous number of these fish is taken annually by anglers—3,480,000 fish, as recorded by license holders, and perhaps an equal number by nonlicensed fishermen as no license is required to take catfish. It will be a surprise to many to learn that the common catfish is taken in such large numbers by anglers and that based on our method of evaluating the anglers' take it has such a high value.

Carp are of very minor importance commercially and are considered a nuisance by anglers.

The spiny-rayed fishes (large-mouthed, small-mouthed and spotted black bass, bluegill and green sunfish, white and black crappie) are of great importance to anglers because of the amounts taken and the sport they furnish. It is illegal to take any of them commercially. The calculated anglers' catch for 1938 is 3,340,000 spiny-rayed fish, although a small amount of the native Sacramento perch (*Archoplites*) is included in the catch record of introduced species.

The most discussed species of fish taken by anglers are the various kinds of trout. Of the 13,420,000 trout taken during 1938 in California, it is estimated by A. C. Taft, Chief of the Bureau of Fish Conservation, Division of Fish and Game, that not more than 20 per cent consisted of the introduced trout. For lack of a better figure, 20 per cent of the total trout catch has been used to represent the take of introduced trout, which consist largely of Loch Leven and eastern brook trout. This would be approximately 2,684,000 fish.

From all the information at hand, an economic appraisal of the introduced species of fish in California results in an annual figure of more than $13,000,000, but with a potential value over a 50-year period of more than $651,000,000.

Of the introduced species, catfish has the highest total value, followed in descending order by the spiny-rayed fishes, trout, striped bass, shad and carp.

FIG. 5. A typical striped bass fishing resort near Martinez, California. Approximately fifty resorts in the bay and river region, each with from 10 to 75 fishing skiffs, depend almost entirely on the striped bass. Hastings Slough, March, 1936.

In addition to food and game fishes, there are other instances of successfully introduced animal life which are of interest to anglers, commercial fishermen and others. These include the mosquito fish, the ornamental gold fish, the Japanese and eastern oysters, and the bull-frog. No attempt has been made to estimate the value of these.

Other papers presented have pointed out the possibilities of economic loss to native or other introduced species because of the introduction of a particular fish. Loss in value due to food competition or

predacious habits of an introduced species is almost impossible to estimate for little data have been assembled on the subject.

The loss of young salmon and trout eaten by striped bass and black bass is not known, although it must be considerable in certain localities. Have the introduced species been the cause of the almost complete destruction of the sturgeon in California? The sturgeon began to decline in abundance shortly after so many species were introduced. One might cite other cases, but it seems useless because of the lack of real evidence. For instance, how many young wild ducks are eaten each year by the introduced bullfrog? Does the value of the frog overshadow the damage it does?

The methods employed in the past to evaluate a fishery have been rather nebulous. Economists and some fisheries people have side-stepped the issue and beat about and around the bush, so to speak. Most people admit that a fishery has value but they seem reluctant to put it into figures. Fish constitute a basic food resource, an important and necessary item of the diet, which is just as vital in many instances as agricultural products.

In addition to the continual dispute over whether or not a fishery is more valuable as a sport or commercial fishery, discussion has arisen pertaining to the value of fresh-water and anadromous fisheries in comparison with other uses of water.

The use of water for irrigation and power developments has overshadowed in almost all cases the value of any affected fishery. If we properly appraise a fishery in all its aspects, as is done for many other industries, which unlike a fishery have no intrinsic value, I think we will find that the fishery may be far more important to the people than has ever been realized. Proper long-term planning of water use for all purposes might produce an entirely different viewpoint as far as fisheries are concerned.

I, for one, am not satisfied with the present methods of fishery evaluation. One is able to ascertain from accurate sources the price paid to a commercial fisherman for a commercial species of fish. However, it seems to many of us that the value of the fishery does not end with the first transaction, *i.e.*, money received by the fisherman. What of the business that is created by the delivery of a load of fish to the pier? What of wages to fish cleaners, truckmen, bookkeepers and plant operators?

Certainly the value of the product is enhanced in its preparation by the wholesaler for the retail market. Likewise, the fishery product increases in value in the retailer's hands, for he in turn creates employment, has overhead in rent and cold storage facilities as well as delivery service. Also, what of the industries related to fishing and marketing, such as net companies, ship chandlers, boat works, engine companies, and suppliers of ice and cold storage? Do they not contribute indirectly to a commercial fisheries value?

Another point which is rarely considered in the evaluation of a fishery is its potential production. Here we have a natural resource which reproduces itself, so that the stock should be considered a capital investment and one which, if properly handled, does not depreciate in value but continues to yield food and money value for an indefinite period of years. In this respect, it is very different from resources

such as oil, gold or other minerals. These are destroyed by utilization, but a fishery resource is like the goose that lays the golden eggs, and it will continue to reward mankind as long as he does not kill the goose. As in all forms of business, a fishery's usefulness, economically, is good only as long as it is well managed and is able to produce a sustained crop year after year.

Capital improvements, as well as investments in new or better equipment, are considered by most enterprises to increase the value of the property or business and are absolutely essential in order to carry on a business and create a product and wealth. Farm buildings and farm equipment, new or better factory machines, as well as increased working space are capital improvement and as such increase the value of a farm or business. Is it not common sense then to consider fishing boats, fishing gear, fish canneries and plants and their improvements from time to time as a "capital improvement?" Such improvements are directly comparable to those mentioned for farm and business and their value certainly should be considered in any appraisal of a fishery.

It seems to me that there is a real need for fisheries workers to crystallize their ideas on the economic appraisal of fishery resources. With an ever increasing population and more and more demand for the use of water for irrigation and electric power, we will have difficulty in maintaining our fresh-water and anadromous fisheries, that is, unless we can demonstrate their value and importance as an irreplaceable and necessary food resource.

PROBLEMS ARISING FROM THE TRANSPLANTATION OF TROUT IN CALIFORNIA[1]

By Osgood R. Smith and Paul R. Needham
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Trout have been transplanted all over the world in efforts to improve angling, especially by Englishmen, who have attempted to take their trout fishing with them wherever they have gone. The trout and salmon fishing in New Zealand is a famous example. Similar efforts have been made in western North America, where eastern brook trout and European brown or Loch Leven trout have been introduced on a broad scale. Native western species, in addition, have been transplanted into barren waters and are badly mixed up in all the major drainage basins. The entire east slope of the Sierra Nevada from Mono Lake south and most of the higher lakes all along the crest of the Sierra Nevada were originally barren of trout. Much of the high altitude fishing in the Cascades and the Rocky Mountains is also the result of man's incurable habit of carrying trout to every remote stream and lake. All this redistribution of trout has been for the sole purpose of producing angling and therefore the problems arising from the transplantation of trout are all related to the practical one of producing fishing.

Though the transplanting of trout to new or so-called barren waters has been highly successful, the results from transplantations to waters where trout are already established have been quite inconsistent. Sometimes an introduced species will establish itself and dominate a stream, sometimes it will exist along with the native species, but more often it will never show up at all. If the success of transplantation is measured by improvement of fishing and immediate returns to the angler from the actual fish planted, it has been uniformly disappointing. This has been true of eastern and European species introduced into the west, of western species introduced in the east, and even true of western species transferred to western streams. Squaw Creek in northern California, for instance, has had both Loch Leven and eastern brook trout planted in it, yet these species rarely appear in anglers' creels (Randle and Cramer, 1941). On the other hand, experiments with marked native rainbows in Squaw Creek have proven that even native species, when planted, do not materially affect the angler's catch. Natural spawning has maintained 97 per cent of the angling.

Once in a while an introduced species does crowd out an established native species. Furnace Brook in Vermont is a good example. Here, careful checks have shown that naturally spawned rainbows are doing much better than the native eastern brook trout (Lord, 1935). Yet the eastern brook trout seems to be able to look after itself, even

[1] This paper was presented at the symposium, "Introduced fishes in waters of the Pacific Coast," at the meetings of the Western Division, American Society of Ichthyologists and Herpetologists, held in Pasadena, California, June 18, 1941.

out of its normal range, for there are streams in the Arapaho National Forest of Colorado in which these exotics have crowded out native species of cut-throat trout. Loch Leven trout frequently become established at the expense of other species. A creel census carried on by the United States Forest Service in New Mexico showed definitely that naturally spawned Loch Leven were replacing native cut-throat in one stream. They seem to be able to maintain their numbers in the face of heavy fishing better than most other species because they are harder to catch. This characteristic has made this exotic generally disliked in California, though many eastern anglers stock Loch Leven in preference to all other species.

The Loch Leven does not seem to do as well as native rainbow and eastern brook trout in cold lakes and streams, but this does not explain its failure to become established in some streams which are apparently ideal. Squaw Creek itself appears to be perfectly suited to Loch Leven, for it is not a cold stream, and spawning conditions appear ideal; yet this species has not established itself in spite of frequent plantings. The same story is true of many California coastal streams, but does this mean that conditions are not suitable for Loch Leven, or merely that planted trout have not overcome environmental resistance, and no other species would do any better?

FIG. 6. Lake Dorothy, Mono County, California, did not have a fish in it until it was stocked with trout. The angling in this lake, as in many others in the high Sierra, will always be dependent upon artificial stocking because there is no suitable tributary in which trout can spawn.

Creel census work throughout the country has shown that artificially planted trout, regardless of species, have a low survival, and that natural spawning, also regardless of species, is producing most of the angling. Exotic species have been stocked repeatedly in the Rocky Mountain region, yet in most places the original native cut-throat is still supplying most of the angling (Needham, 1938.2).

Wherever the fish being planted can be distinguished from those already established, whether they are native or not, the immediate results have been disappointing. It would seem logical that the frequent failure of exotic fish to establish themselves, even after long periods, might be caused by the failure of the initial planting rather than by a specific lack of adaptability. In many cases the failures seem to be related to planting methods, unknown physiological conditions developed by life in hatcheries, or to the environmental resistance in the particular waters in which they are planted.

One factor which might contribute to many planting failures is that practically all of the hatchery stocks are of mixed or of unknown origin. This is true for the obviously foreign Loch Leven and eastern brook, and also for the so-called native species. It has been caused by a failure to keep accurate records in the early days of fish culture, and the meddling nature of man, which has led him to cross almost all species of trout, usually just to see if it would work. As a consequence, rainbow trout planted in a stream may have inherited a migratory tendency which will lead them downstream to polluted waters or into diversions from which there is no return. Or, again, these hatchery hybrids may mix with native stocks and produce offspring of low fertility. Embody (1934) pointed out that "Few species show such a wide variation in the quality of the eggs as do our eastern rainbow trout. They may have started as pure Shasta rainbows, but now we find them badly mixed with Oregon steelhead and other races of the migratory steelhead-rainbow aggregation. In many cases where these hybrids are kept as breeders, the eggs are below standard." The western hatchery stocks are about as badly mixed up as the eastern ones, partly due to the fact that some of the rainbow brood stocks have been imported from eastern hatcheries.

It seems evident that a careful study of the hereditary background of hatchery brood stocks should be undertaken in order to plant the offspring in waters to which they are adapted. Selective breeding of trout has already greatly increased the possibilities of hatchery production, but the adaptability of domestic strains to hatchery life does not necessarily prove that their offspring will be equally well suited to stream life. A start was made on the development of a pure strain in 1937 when the United States Bureau of Fisheries brought *Salmo nelsoni* north from Mexico (Needham, 1938.1).

Even if we started with a pure strain, we would not be sure of the best places to plant them, for little is known of the ecological or physiological requirements. Sometimes fish from one hatchery will not survive in a certain stream where the same species, from another hatchery, will do well. Obviously, something other than species characteristics is involved in these cases.

Introduced fish may fail to establish themselves or show up in anglers' creels because they migrate out of the area planted, and this is one of the weak points in much of the creel census data. Trapping studies on Convict Creek in California and catch records elsewhere indicate that there are occasionally pronounced downstream movements of fish, apparently not associated with spawning migrations. Both Loch Leven and rainbows do this, and it seems quite likely that such a tendency might cause planted fish to leave a given stream.

Creel census studies by Shetter and Hazzard (1941) indicate that rainbow trout tend to migrate more than either Loch Leven or eastern brook. This, to be sure, occurred in Michigan, where the rainbow is one of the exotic species, but this species behaves the same way in California. In this respect, at least, the introduced species might be more valuable.

An all too common lack of care in planting trout may account for some of the low returns or the failure of exotics to become established. Usually large numbers of fish are dumped in one, or at least relatively few, spots along a stream because there is neither time nor man power enough to distribute them evenly. This practice may cause enormous losses because it is very different from the natural method of restock-

FIG. 7. The Convict Creek Experiment Station, north of Bishop, California, where field experiments on trout planting and other problems are being conducted by the U. S. Fish and Wildlife Service, in cooperation with the U. S. Forest Service and the California Division of Fish and Game.

ing. Naturally spawned fish come out of the gravel well distributed along the average stream and, furthermore, they do not all come out at one time. Preliminary observations on natural spawning at the Convict Creek Experiment Station near Bishop, California, indicate that the fry from one pair of spawning trout come out of the gravel over a period of about ten days, and, since the adults do not all spawn at the same time, the fry start life well distributed both in time and space.

It is possible that planted fish do not improve the fishing to any great extent merely because the numbers planted are very small in proportion to those already present, as Curtis (1941) pointed out. Low returns do not mean that the planted fish necessarily have a lower survival than the wild fish present. Foerster (1936), working with sockeye salmon, found a survival rate of 1 to 3 per cent from natural spawning, and for hatchery-produced fry a survival of 1.7 to 4.5 per

cent. Heavy mortalities should be considered normal, and there is no reason to suppose that planted fish, once turned out to fend for themselves, would fare any better. With an expected mortality of almost 99 per cent, it would take a great many planted fish to affect the angling; and, for the same reason, introduced exotic fish might easily fail to become established if any accident should wipe out the few survivors.

Accurate records have been kept for a few trout streams, notably Squaw Creek in California and Furnace Brook in Vermont, mentioned above, the St. Mary River in Virginia (Surber, 1940), and various streams in the Pisgah National Forest of North Carolina. Sample records have been taken on many other streams both east and west. The angling returns from planted fish have ranged from an extreme high of 70 per cent for large catchable sized fish planted during the fishing season in New Hampshire (Hoover and Johnson, 1938) to around 1 per cent or nothing at all for the smaller 1½ or 3-inch fish usually planted. Returns from large fish planted during the season have usually been around 20 per cent or less, and for fingerlings, returns have usually been less than 1 per cent.

Plantings in lakes generally have been more successful than in streams. Experiments in upper Angora Lake, near Lake Tahoe, California, have shown returns to the angler of 25.6 per cent when 5-inch eastern brook trout were planted (Needham, in press). In one year 77 per cent of the fish caught were marked fish. Fishermen report similar high returns from an intensive stocking program with rainbows by the California Division of Fish and Game in June Lake, Convict Lake and other accessible waters which can be stocked with large quantities of fair sized fish. The experiences indicate that artificial stocking can produce fish for the anglers if stocking is intensive enough. In other words, fishing for either native or exotic fish can be improved artificially, but it is going to take more fish and more money than we have planned on.

Planting larger fish reduces the loss from mortality, but it does not supply the complete answer to stocking problems. The larger the fish, the more they cost to raise. A higher survival should balance the cost. Furthermore, Hoover and Johnson (1938) and Hazzard and Shetter (1939) have found that heavy plants of large fish during the fishing season tended to increase fishing pressure which depleted wild brood stocks to low levels. The planting of large catchable trout during the season is effective, but in streams, at least, it appears to be a sort of "shot in the arm," to be applied in cases of extremely heavy fishing, where wild fish can not be expected to survive and to spawn. In brief, we may (1) stock for the creel or (2) stock for reproduction. In the first instance, large fish are planted in the course of the fishing season with the expectation that practically all of them will be caught out in a short time. In the second instance, usually small fish are planted with the expectation that some will survive to build up spawning stocks for natural reproduction, or to maintain stocks where there is no natural reproduction, as in high mountain lakes.

The answers to trout planting problems can be secured only by a continuing program of experimental field investigations made on selected streams and lakes. Creel census work on both introduced and

native species, coupled with studies of the efficiency of natural spawning and studies of survivals of planted fish in controlled streams, will eventually lead to better stocking and management of trout waters.

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CARP CONTROL WORK IN LAKE ALMANOR, 1941 [1]

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Lake Almanor, which is situated on the north fork of the Feather River in Plumas County, is at present the largest artificial lake in California. Conditions in this reservoir were formerly more conducive to the production of native rainbow trout than they seem to be at present. In addition, the number of carp in the lake has been much greater in the past few years and many people feel that the carp are probably responsible for the decrease in the supply of trout. Although no facts are at present available to support this view, carp do have an adverse effect upon the more desirable fish in some bodies of water, and it was felt that control methods could be experimented with in Lake Almanor to advantage.

The most effective methods of carp control are netting and poisoning. There is no question but what trapping or seining of carp is superior to poisoning when the fish are to be used for food. Not that the poison will render them inedible but the markets frequently require the carp to be alive or very fresh, and in addition shipments to market can be delayed when the fish are trapped whereas this is not possible if they have been killed by poison. However, if the carp are to be processed nearby they may be poisoned, collected and used successfully. Both trapping and poisoning were tried on Lake Almanor.

In the fall of 1940, a carp trap was built on a spring-fed stream entering the north end of the lake at a point known as Gould's Swamp where the carp spawn in the spring of the year. The trap consisted of two strong woven-wire fences built across the main channel of the stream, about 200 yards apart. In the lower fence was a V-shaped opening through which the carp could enter the enclosed section. The upper fence of course was fish-tight. Lighter fences were built across side channels to prevent the fish from migrating around the trap section. The plan was to seine out the carp which would become trapped between the two main channel fences during their spawning migration to the shallow swamp above.

The level of the lake was higher during the spawning period of 1941 than was anticipated and most of the carp swam around the trap fences and could not be caught. However, the trapping of carp in Lake Almanor, at least, is entirely feasible providing one knows the approximate height which the lake will reach during the spawning period. The trap should be made with angle-iron posts and heavy woven-wire fencing. It could consist of two parallel fences across a channel or a circular corral-like structure, depending on its location.

[1] Submitted for publication, September, 1941. Photographs by author. Note: All persons are advised against attempting any kind of fish control by poison or any other method, as such action constitutes a violation of State law. Call on the nearest representative of the California Division of Fish and Game if you think control measures are necessary.

It is necessary to fold the wire in at the bottom to make an apron. This apron should then be staked securely so that the carp can not root under it. One or more V-shaped openings should be located so that the fish migrating toward their spawning area will enter readily.

FIG. 8. Gould's Swamp, Lake Almanor, May, 1941. The carp trap was located on this stream, and poisoning was carried on in the shallow areas in the right background.

The use of powdered derris or timbo root has been described by several fisheries biologists but usually it is employed in waters which are to be completely poisoned. Thus, relatively small lakes or stretches of stream, even ocean tide-pools, can be completely freed of fish life. The present description is of a method of controlling an undesirable species without affecting the more desirable ones. Selective poisoning with powdered derris root was reported by Greenbank[2] for a Michigan lake. Greenbank also reports selective poisoning of Fish Lake, Utah, in 1938, by Stillman Wright.

Lake Almanor is not particularly well adapted to the control poisoning of carp but certain swamps and shallow indentations in its shore line are frequented by the spawning fish and here they can be poisoned with great ease. Long, narrow, shallow inlets in a lake shore

[2] Greenbank, John. Selective poisoning of fish. American Fisheries Society. Transactions, vol. 70, 1940, pp. 80-86, 1941.

are ideal, providing of course that the carp are present in large numbers and that the water temperature is high. In work at Lake Almanor it was found that temperatures ranging from 75° to 85° F. were suitable for poisoning. Some spawning may occur in waters cooler than 75° but the fish would be more easily frightened and it would require more poison to stop them before they could escape into the open lake.

To illustrate the method let us suppose that we have a cove in the lake shore which is 300 to 600 feet long, 100 feet across the mouth and about 3 feet deep. The water temperature ranges from 75° to 85° F. and there are hundreds or even thousands of carp spawning in the

FIG. 9. Carp spawning in shallow water of Lake Almanor's north shore, May, 1941. Note the fish thrashing about in the spawning act. Control work, both trapping and poisoning, can be carried on most readily when the carp move into shallow water to spawn.

cove. The object is to kill all the fish before they can take alarm and depart for the open lake.

Floating a tub full of thin "mud" made of timbo or derris powder ahead of him, the operator slowly wades across the mouth of the cove, thoroughly spreading a "curtain" of the poison from one side to the

other. Then by working back and forth across the mouth, each time a little farther into the cove, a heavily poisoned strip is formed which may be about 50 feet wide. Then the operator proceeds directly through the center of the cove broadcasting the thin "mud" on either side of him. Those fish which are near the mouth will try to escape but before they have passed through the curtain of poison across the mouth they will have absorbed enough to kill them on the spot, or if they do reach the lake they soon die. The strength of the poison in this so-called curtain formed across the mouth was not determined in the work at Lake Almanor, but it should be strong enough to make the water distinctly roily as though it contained a heavy suspension of actual mud. When the water is warm a carp can not, or at least does not, swim through it rapidly enough to avoid being killed. This system can be used in shallow bays or even along the open shore if a large semicircular curtain of the poison is first laid down.

However, under such conditions the results are ordinarily not commensurate with the costs. Poisoning was attempted when the water temperature was 68° F. but the fish became frightened and escaped through the poison without heavy losses. In practice we found that when conditions were good the carp became groggy in five minutes and died in fifteen.

In some of the coves in Lake Almanor we succeeded in killing from 1000 to 1500 carp at each operation. The number of carp killed by poisoning in Lake Almanor in 1941 was estimated at between 10,000 and 12,000. With conditions fairly opportune and with the experience gained in the past season it should be possible to poison at least 15,000 adult carp each year. This work can be done by two men, and about 300 pounds of powdered timbo or derris would be used.

The best results can be secured between May 1 and June 15 in Lake Almanor, though even after the fish have finished spawning and while they are up in the shallow areas feeding they can be poisoned. At such a time the young carp, which would be about one-half inch long, could be killed. Effective poisoning might be continued throughout the summer, at least well into July.

It was found that all the carp could be killed in a cove and even if they were left to decay, more carp would come into that same cove later in the season to spawn. Perhaps three weeks would elapse before fish would enter a previously poisoned cove, but they could be expected to use it again for spawning if the first poisoning was not made too late in the season.

It should be remembered that it takes much longer to collect and pile large carp or otherwise dispose of them than it does to kill them. Therefore, if the fish must be removed from the water the number poisoned may have to be limited. Large carp decompose quite thoroughly in three weeks and if they are not too offensive it is best to let nature dispose of them. In Almanor the areas of poisoning were so situated that few fish floated to sections of the lake shore where they would be disagreeable.

There were few desirable fish in the shallow, warm areas of Lake Almanor which were poisoned. Most of the fish, other than carp,

which were killed were red-sided minnows (*Richardsonius egregius*). Aside from these were a very few bluegills, catfish and chubs (*Siphateles*). Only one trout fingerling was known to have been killed by the poison and we have no reason to think that more, young or old, were affected. The poison becomes greatly diluted as it spreads out into the lake and can then do no injury.

Two interesting observations were made during the operations in this lake. One was that a large part of the carp eggs which become

FIG. 10. Poisoned carp collected in piles, Gould's Swamp, Lake Almanor, May, 1941. Over 10,000 adult carp were poisoned during the control work in 1941.

fastened to marginal grass or to floating wood become fungused and die. The proportion of eggs so affected probably ranges around 50 per cent, running as high as 75 per cent in some areas observed. The second fact is that remarkably few immature carp were observed. Not over ten yearlings and three two-year-old carp were known to have been killed by poison. It might be thought that fish of these ages, being immature, simply were not in the spawning areas. This is more or less true, no doubt, but resort owners on the lake all say that they have seen none or almost no young carp in the past few years, whereas large numbers were seen previously. It would appear that some destructive natural control is operative and we may soon have a period when carp are much less abundant than they have been.

From scale examinations it appears that first maturity is in the third year for most females and that the spawning population is made up of three-, four- and five-year-old fish. We saw no carp which would weigh over 15 pounds and the average was about seven pounds. There was remarkable uniformity in size and neither sex seemed to predominate.

In spawning it was customary for three to five males to follow a female about until she was ready to eject her eggs, then one male would rush beside her and they would thrash about, ejecting milt and eggs. When spawning occurred in the areas filled with floating dead trees, the fish would try to spawn the eggs on or alongside these trees so that the eggs could become attached to them.

It seems probable that by systematically poisoning the carp in Lake Almanor, the number of these fish can be noticeably reduced. This method of destruction of course is nothing more than a control measure but occasionally it may be that partial eradication is more desirable than total extermination. This would be true where a fish with some forage value has become too abundant and endangers the desirable species either by eating them or by eating their food.

ROUGH FISH CONTROL IN GULL LAKE, MONO COUNTY, CALIFORNIA[1]

By Elden H. Vestal
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INTRODUCTION

The Gull Lake rough fish control experiment had its inception in August, 1939, when investigations were begun by the writer to determine the status of rough fish in Gull Lake in relation to that of trout.

Gull Lake once furnished excellent eastern brook trout fishing and was utilized by the California Division of Fish and Game as a highly profitable source of eggs for trout culture. The lake chub (*Siphateles obesus*), a minnow native to the Lahontan Basin, was introduced into the lake about 1934 as bait. Very prolific and not subjected to fishing drain, it increased until it had almost crowded the trout out. Some individuals reached a length of nine inches, and in midsummer schools of young chubs up to two and one-half inches long blackened the shallows. Angling practically ceased and the taking of trout eggs was abandoned.

Of the different plans suggested for control of the rough fish, the most practical, in view of the economical results obtained in eastern waters, appeared to be chemical treatment with rotenone, a poison derived from certain tropical plants. Since powdered timbo (*Lonchocarpus urucu*) from Brazil, with warranted rotenone content of 5 per cent, had been used successfully in other States and was considerably lower in price than other commercial plant derivatives containing the same amount of rotenone, it was decided to use this preparation.

Although the immediate purpose of the experiment was to eliminate the rough fish from Gull Lake, its wider and more generalized intent was to demonstrate to California sportsmen the latest method for effective, quick and economical reclamation of waters once valuable as producers of trout and other game fish.

The present paper reports the results of three phases of the Gull Lake fisheries project: (1) preparatory stages, chemical treatment and elimination of rough fish; (2) observations and tests made during the period required for natural recovery, with ultimate restocking of the lake; and (3) yield of trout to the angler in the first season after stocking.

The project was a success as all the chubs in the lake were believed to have been killed, and following restocking with trout, excellent fishing was had the following season (1941).

[1] Submitted for publication, December, 1941.

Note.—All persons are advised against attempting any kind of fish control by poison or any other method, as such action constitutes a violation of State law. Call on the nearest representative of the California Division of Fish and Game if you think control measures are necessary.

FIG. 11. View of Gull Lake looking southwest toward Mt. Lyell (extreme right of distant horizon). Photograph by author, July 24, 1940.

I am indebted to a number of persons for much help in the Gull Lake project and I am pleased to record their names. Mr. Theodore Hookway assisted with soundings and pacing of the Gull Lake shore during survey work in 1939. My wife, Ethel Vestal, recorded and otherwise assisted with detailed soundings, preparation of individual instruction maps and lake mapping during survey work on Gull Lake in 1940. Messrs. Gerth of June Lake contributed freely of time, private equipment of a wide variety, and assistance in person to the project and greatly speeded up preparations before and return of equipment following the rough fish control experiment. Mr. George Conn, also of June Lake, granted the use of June Lodge for meetings of personnel and loaned equipment and persons in his employ to assist in the project. To all the residents and townspeople of June Lake and of Horseshoe Valley, who loaned various and sundry equipment for use in the Gull Lake project, I express my sincere thanks.

For the earnest help given me by all the personnel in the Gull Lake project I am indeed grateful and include in this category the following persons: Messrs. Robert Gerth, Sr., Claude Walborn, Wallace Gerth and L. L. Tatum, leaders in the project; and George McSweeny, Hercel P. Clouse, Robert Gerth, Jr., H. Byrnes, Russell C. Brinley, Walter Utter, Edward H. Gahn, George W. Conn, Richard Conn, Sheridan Meadows, Vernon Meacham, J. D. Humiston, Robert Hankins, R. C. Combes, Frank Wright, Robert Mahoney, Robert Condy, Dick Almour, Hugh Morris, Ralph Cook, George Pruitt, Jack Miexsell, H. B. Hitchens, Bud Lanham, H. E. Rider, John Marquette, Claude Claudel, Thomas McKee, R. C. Lewis, Charles Cuddigan, Leon Talbott,

I. H. Hussey, George McCloud, Douglas Condie, Sydney Griggs, and Fish and Game Wardens Carl Walters, Webb Talbott and Al Crocker.

I am grateful to the Mono National Forest for the loan of some equipment and the following men from the Civilian Conservation Corps to the project: Walter Letscher, Zenon Holody, Walter Ramanko, Francis Tobin, Benjamin Johnson, William Poos, Boyd Minto, Louis Pereoski, James Romanelli, and Edward Wszalek.

To Supervisor Walter Dombrowski of Homer Township and to Mono County I am indebted for important assistance from both men and equipment.

To the United States Fish and Wildlife Service station at Convict Creek experimental stream I am indebted for the loan and use of some equipment to aid in the project.

For much help in the revision for publication of the original report to the Bureau of Fish Conservation, I am indebted to Mr. Brian Curtis, Supervising Fisheries Biologist, of the Division.

Finally, to all others who helped in various ways to make the project a success, I express my gratitude.

PREPARATIONS FOR THE EXPERIMENT

Survey of Gull Lake

Hydrographic and Physical Features

Gull Lake is located at an elevation of 7,588 feet. It is one of four glacial lakes in the Reverse Creek recreation area of central Mono County, California. The lake is roughly medallion-shaped with a large granite promontory rising in the center of the south margin.

The principal inlet stream is derived from June Lake, which is located about one-fourth mile north, and enters Gull Lake in nearly the center of the north shore. The inlet stream reaches a maximum flow of about one cubic foot per second in winter and early spring. Other inlet streams originate from springs on the east side of the lake and flow up to 100 gallons per minute with little annual fluctuation in volume. Small trickles, varying from one-half to two gallons per minute, flow from springs located on the west side of the lake margin. Seepage and surface runoff are major supplies of water to the lake.

The outlet of Gull Lake is located in the southeast corner and gives rise to Reverse Creek proper. Measurements of flow by the writer have shown extremes from 0.25 cubic feet per second on July 5, 1940, to 3 cubic feet per second on January 17, 1941.

Soundings and measurements of Gull Lake, combined with study of a hydrographic map prepared by the Department of Water and Power of the City of Los Angeles, revealed the following data. (See also Fig. 12.)

Maximum depth	63 feet, 8 inches
Average depth (125 soundings)	$37\frac{1}{2}$ feet
Area of water surface	68.6 acres

Between date of measurement (August 11, 1940) and date of chemical treatment, the water level had declined about six inches. Therefore the total volume of Gull Lake as of September 11, 1940, was computed at 2,537 acre-feet, or 826,041,950 gallons.

The north shore of Gull Lake is mostly beach of granite sand; the beach grades into a more abrupt and rocky shore of glacial till along the west side; a marsh occurs in the extreme western portion of the lake and gives way to an abruptly rocky margin along the south side; and finally, the east margin is mostly abrupt and wooded. Well over half of the entire shore line is bordered by willows. Willows, with their dense root mass, tend greatly to preserve the identity of the shore line in lakes and streams.

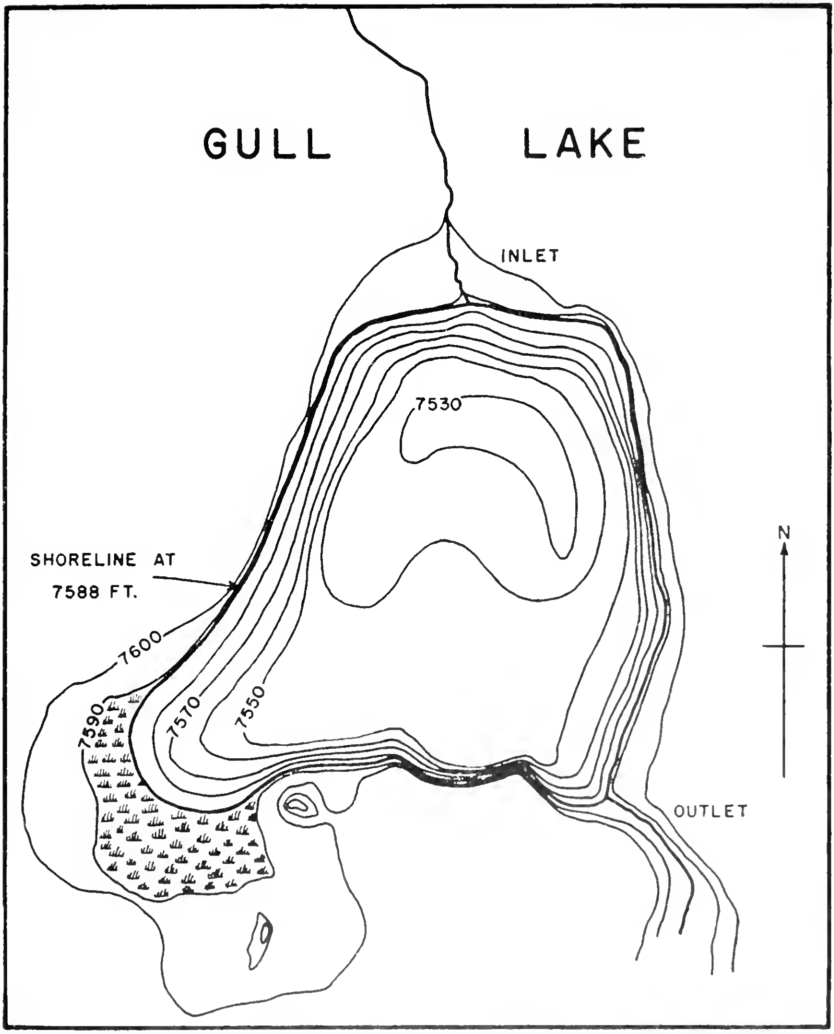

FIG. 12. Hydrographic map of Gull Lake, Mono County, California. From a map prepared by the Department of Water and Power of the City of Los Angeles. Compare with figure 13.

The bottom consists mostly of mud and silt; large areas are made up of decomposed pumice ash, probably from the eruption, in prehistoric times, of the Mono Craters.

Gull Lake freezes in winter, usually to a depth of 8 inches. Certain temperature readings are given below:

August 7, 1939, 10.30 a.m. surface------------------68° F.
July 11, 1940, 3 p.m., surface------------------------72° F.
September 17, 1940, 3 p.m., surface----------------59.5° F.
September 17, 1940, at 60-foot depth----------------49° F.

During the summer months and into the fall of the year Gull Lake is usually calm in the early morning and until about 9 a.m., when a breeze rising in the south ripples the lake surface. By late afternoon the lake is frequently in small whitecaps as the wind reaches its maximum velocity for the day; this is usually from 20 to 25 miles per hour. Winds of high velocity across the lake are infrequent, but are known to reach about 75 miles per hour.

In its present character, Gull Lake is a product of the last or Tioga glacial period.

Biological Features

Especially along the west and southwest margins and in the southeast corner, Gull Lake has a good growth of emergent aquatic plants. The ivy-leafed duckweed (*Lemna trisulca*) is common, and a dense growth of rushes and reeds (genera and species undetermined) forms a marsh extending over five acres along the west side and in the west corner of the lake. Submerged plants also form a good stand in the lake and again occur mostly in the western and southeastern sections. The most common submerged plants are *Potamogeton*, *Myriophyllum*, *Spirogyra*, *Nitella*, and *Isoetes* or quillwort.

Some information on available fish foods in the lake was gained from the analyses of stomach contents of 14 eastern brook trout (*Salvelinus fontinalis*), 9 to 14 inches long, taken in two six-hour gill net sets during the days of October 22 and 23, 1939. The results of the analyses are incorporated in table 1.

TABLE 1

Foods Eaten by Fourteen Eastern Brook in Gull Lake in October, 1939

Items eaten	*No. of stomachs containing items*
Damselfly larvae	11
Scuds (*Gammarus* sp.)	10
Snails (*Planorbis* sp.)	9
Dragonfly larvae	5
Caddice larvae and cases	3
Beetle larvae (*Hydroporis* sp.)	2
Mayfly larvae	2
Water mites	1
Leeches	1
Corn grains	1
Debris	9

Other food organisms observed from plankton samples, bottom samples, in or about the aquatic plants in the lake, or along the rocky shores included water striders, back swimmers, water boatmen, numerous small limpets, oligochaetes, *Corethra*, midge larvae, pupae, and adults, and adult dragonflies, damselflies and mayflies. Predominant plankton organisms in Gull Lake are the cladocerans (*Daphnia* and *Ceriodaphnia*) and the copepod *Cyclops;* others observed include the rotifer (*Anuraea cochlearis*) and *Nostoc*.

Originally, Gull Lake was stocked with cut-throat trout (*Salmo henshawi*). These were soon replaced with Loch Leven (*Salmo trutta*). Eastern brook trout were later planted and became the predominant species of fish in Gull Lake until their numbers were superseded by lake chubs. An occasional rainbow trout (*Salmo gairdnerii*) was taken up to 1939. Although suckers and sticklebacks (*Gasterosteus aculeatus*) were said to be present, none was observed by the writer.

Vertebrates, other than fishes, which were observed in or about the lake included frogs (two species), toads (one species), garter snakes (one species), and a number of fish-eating and aquatic birds, including western belted kingfishers, American egrets, a great blue heron, a Farallon cormorant, common loons, pied-billed grebes, eared grebes, one American bittern, California gulls, Canada geese, greater scaup, ruddy ducks, cinnamon teal, redhead ducks, and pintail ducks.

Experiments with Derris and Timbo Powders

Properties of Rotenone

Rotenone, with the formula $C_{23}H_{22}O_6$, is present in derris, cube and timbo roots, of which it is the most effective constituent, although deguelen and tephrosin are also active ingredients. The powders are dispensed commercially. They resemble breakfast cocoa in texture but in color are light tan to buff.

Regarding the toxic properties of derris root (and the same applies to timbo), W. M. Hoskins, Associate Professor of Entomology at the University of California, had this to say in a letter of August 25, 1939: "The toxic constituents of derris root are very slightly soluble in water and hence when concentrated extracts are desired they must be made in an organic solvent. The concentrations effective versus insects are not harmful to man or animals."

Experiments on Fishes

In order to determine the action of rotenone on fish, a number of experiments was performed with these vertebrates during the period of preparation for the major Gull Lake experiment. Rainbow trout, lake chubs from Gull Lake, and sticklebacks were used. Most of the earlier experimental work was done with derris powder but little, if any, difference at all was noted when later experiments gave ample opportunity to compare the action of both derris and timbo powders under similar conditions.

A few of the earlier experiments are summarized below:

Fish used	*Proportion of derris to water by weight*	*Water temperature F.*	*Time until*	
			Loss of Equilibrium	*Death*
7 lake chubs	1:33,000	58°	19 min.	1 hr.
14 lake chubs	1:40,000	58°	12 min.	1 hr.
7 lake chubs	1:66,000	58°	12 min.	1 hr.
10 lake chubs	1:1,000,000	59°	35 min.	2 hrs.
5 lake chubs (from 2 to 3 inches)*	1:2,000,000	48° at start 58° at end of 4 hrs.	2 hrs.	5 hrs.

* One chub removed to fresh water at end of 4 hours recovered fully.

Experiments of this kind with rotenone were repeated again and again and revealed a number of characteristics in its action. Provided they were removed to fresh, cold, aerated water soon after loss of equilibrium, chubs of any size regained equilibrium and eventually fully recovered. Failure to remove the fish to fresh water after a certain length of time, or beyond an inferred threshhold of tolerance for the poison, resulted in the death of the fish.

The action of rotenone assumed a definite pattern with little variation in each species of fish used. Following the usual rise to the surface, the fish soon lost equilibrium and apparently all sensation. There quickly followed a period of chaotic gyrations and swimming in helter-skelter fashion in which the fish seemed unable to regain control of itself. Cessation of the locomotor movements usually caused the fish slowly to turn belly up and sink gradually to the bottom of the experimental container. In the final period, the fish usually exhibited very weak opercular movements and seemed unable to swim any longer. Death occurred very shortly after the fish exhibited a series of curious shuddering and spasmodic quivering motions, involving usually the entire body. Frequently, the fins were rigidly extended as a final movement.

The specific action of rotenone on fish, as determined by experimenters elsewhere, is primarily histolytic; that is to say, the layer of epithelial cells covering the gill lamellae and tiny gill filaments is destroyed. Loss of equilibrium in the fish follows when interchange of gases through the gill epithelium between the blood cells and the surrounding aquatic medium is no longer sufficient and waste products surcharge the blood. Almost simultaneously, powers of sense are lost and the fish enters the characteristic period of helter-skelter swimming described above. From the time that equilibrium is lost the fish is powerless to aid itself and seemingly fails to react to anything but internal stimuli.

Fish of smaller size were overcome by the action of rotenone sooner than larger fish.

No great difference was noted in the action of rotenone on trout. Trout of different sizes usually were overcome sooner than any of the rough fish of comparable size. The first indication of the action of rotenone in trout was a gaping and shaking of the head at intervals; this was not seen to occur in chubs or sticklebacks. The characteristic period of chaotic swimming, following the loss of equilibrium, appeared to be more vigorous and of less duration in the trout.

Sticklebacks seemed to be more resistant to the action of the chemical than either the chubs or the trout and withstood various concentrations for nearly twice the length of time required by the other fish to cease movement. Extension of the spines in rigid fashion seemed to be a characteristic end-movement in sticklebacks at the time of death.

The finding from the experiments that chubs or trout could be rescued, presumably before the action of the rotenone had injured the majority of gill surface, suggested that during the major experiment in Gull Lake many trout might be saved, provided live cars or aeration equipment and fresh water were at hand. Accordingly, preparations were made for the rescue of as many trout from the lake as it was possible to net.

Experiments on Higher Vertebrates

Using a concentration of derris and water (1:100,000) a garter snake about 20 inches long was repeatedly immersed in the solution for 3½ hours. At the end of the trial the snake was released and seemed not the slightest affected by the solution.

Fresh solutions of derris and water (1:66,000 and 1:100,000) were force-fed with an eyedropper to a Brewer blackbird, two sagebrush chipmunks, a golden-mantled ground squirrel and a domestic sheep. No distress and only the apparent discomfort of being force-fed was observed in the animals used.

The writer himself on one occasion drank a cupful of the treated solution, derris and water (1:2,000,000). In another trial nearly a cupful of solution at 1:1,500,000 was swallowed. Neither ill effect nor discomfort whatsoever was noted from the mixtures. In fact, no difference could be distinguished between the taste of treated and untreated water from Fern Creek where the tests were made.

Experiments on Aquatic Plant Life

Water plants (*Nitella*, *Potamogeton*, *Spirogyra* and some other green algae) were allowed to remain in a hatchery trough of derris and water (1:100,000) for four days. Meantime, two lots of chubs, totaling 15 fish, placed in the trough were quickly killed. At the end of four days, microscopic examination of sections of the plants (in addition to observation of their general appearance) showed them to be alive and apparently in good condition. Only minor changes within the plant cells were noticeable.

Experiments with Mixing and Distributing Chemical

In order to determine the most effective mixture and means for distribution of derris and timbo in a large body of water, a number of tests was made in the laboratory and in Gull Lake with the powders. In order to economize chemical, tests on distribution were also made with fine clay in a suspension that most nearly resembled that of derris or timbo mud.

Dry derris and timbo powder thrown broadcast on the surface of the water and then churned, distributed poorly and with uncertain results. It was impossible to treat a particular section of water well

in this manner. More often wind carried the powder at random over the surface of the water.

In the laboratory experiments two methods of preparing the powder for distribution on a small scale proved effective. In the first method exact amounts of the chemical were weighed out and stored in stoppered vials for later use. When ready to use, the vial was filled two-thirds full with fresh water, stoppered and the contents shaken vigorously until all the chemical was in suspension. The solution was then added to a larger quantity of fresh water in an experimental container. In the second method, to an exact amount of the powder in a teaspoon or tablespoon, drops of water were added sufficient to make a paste of moderate consistency. The mixture in the spoon was then gradually stirred into the larger quantity of fresh water in the experimental tank. In both instances repeated stirring gradually gave a uniform distribution.

In the laboratory a consistency most suitable for immediate dissemination through a cloth or burlap container was found when water was added to the powder in approximately the proportions 2:1 by weight. The materials were then mixed until all particles of the powder were moistened.

It was found in Gull Lake that such a mud of derris or timbo, when trolled in a cloth or burlap container in the propeller wash of an outboard motor, gave out an expanding cloud of chemical in the wake of the boat. Thin mixtures, resembling the consistency of hotcake batter, spread too rapidly and it was necessary to thicken them with more powder to enable greater uniformity in spreading the chemical through the water. Following the spreading of the well-mixed mud, the chemical would descend vertically much as a fog through the water and, even without further churning of the water, currents and wind would soon effect a complete distribution. The latter result suggested that in the distribution of the chemical in the major experiment there might be considerable latitude.

In the mixing of relatively large amounts of the powders it was found that water was absorbed with surprising rapidity at first and the whole batch of mud seemed to swell slightly. To guard against scattering and inhalation of the powder, addition of powder and mixing were done slowly until all the powder was dampened.

There was no greater concern in the trolling experiments than the tests on penetration of chemical into marginal water and the dense reed and marsh areas at the south and west ends of Gull Lake where great numbers of young chubs were seen. Together with Robert Gerth, Sr., the writer used a large twin outboard motor to test penetration in such areas by means of propeller wash. The mixture tried was of fine clay and water to make a thin mud. The mixture remained in suspension very well and it was possible to follow the progress of the propeller wash in forcing the colored water into the marsh. At first it was thought possible to control the wash by anchoring the boat, with one large anchor on each side. When the anchors would not hold, repeated turns at particular locations were made with the boat traveling at high speed. Little by little muddy water was forced to a considerable distance into the reed beds. But the uncertainty of results with this method

alone suggested to the writer that a combination of several methods of distribution would probably effect a more uniform and complete dispersal of chemical throughout such critical areas. Equipment was not available prior to the major experiment to test the full combination of methods planned for the actual experiment.

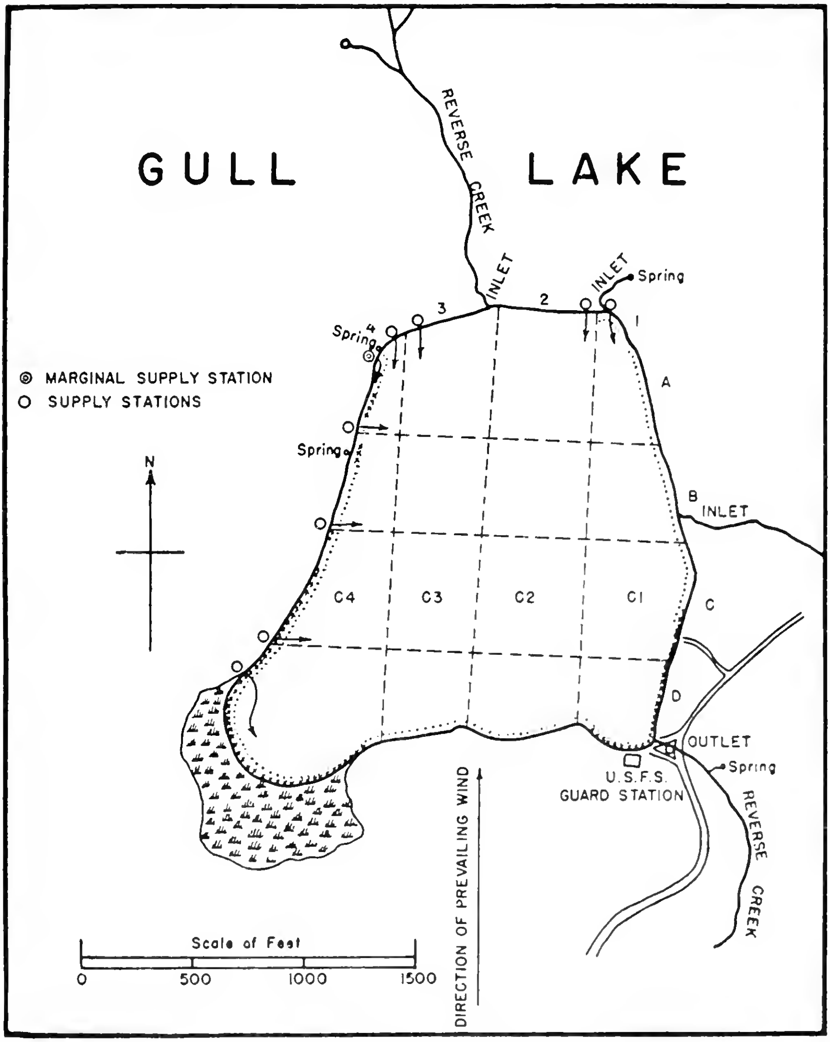

FIG. 13. Map of Gull Lake, showing stations and lanes used in rough fish control experiment, September, 1940. Dotted line marks the marginal zone; xxx note location of emergent rushes. Similar maps, with field notations, were supplied to the men participating in the experiment.

Periodic Testing of Stored Timbo Powder

Timbo powder for use in the major experiment, encased in heavy brown bags and, in turn, packed in protective wooden cases, was

shipped to Mt. Whitney Hatchery near Independence, Inyo County, California, and stored until the date set for its use in Gull Lake. Periodically small samples were taken at random from the different cases for testing to determine whether any loss in strength of ingredients had occurred while the material was in storage. All tests were made with chubs at Gull Lake and concentrations from 1:100,000 to 1:3,000,000 were tried. Up to the final series of tests on the day prior to the chemical treatment of Gull Lake, no loss in strength of ingredients was detected, as judged by the time required in different concentrations for the action of rotenone on the fish. Moreover, no difference was found between the action of timbo during the tests and the action of the derris as used in earlier experiments in the laboratory. It should be noted that both timbo and derris powder stored in stoppered vials for laboratory use turn dark and collect mold unless the vials are thoroughly dried after cleaning.

Plan of the Major Experiment

Subdivision of Gull Lake

In order to effect a more uniform distribution of timbo mud, Gull Lake was subdivided with comparatively uniform allotments of chemical set aside for each subdivision. The open water of the lake was divided into 16 sections (see Fig. 13), each of which was to receive chemical treatment in two directions: One two-man power boat was to operate west to east in each of the lanes A, B, C, D; and one boat north to south in each of the lanes 1, 2, 3, 4. The lake was further divided into a marginal zone of four sections in which one two-man power boat was assigned to troll chemical while three two-man large boats, equipped with mechanized portable pumps, in three overlapping zones pumped the supertreated marginal water back into the extreme marginal areas, paying particular attention to inlet streams, springs, and to all reed and marsh areas. The marginal zone for trolling consisted of a strip of water averaging 25 feet wide, extending from section A4, where the station for supply of chemical was located, completely around the lake margin to section A1 (see again Fig. 13). The three overlapping zones for pumping heavily treated marginal water consisted of (1) the marginal zone from center west to center south, (2) from center south to center east, and (3) from center east back to center west.

On shore, six men were assigned to treat the critical marginal areas in coordination with the marginal troller and the marginal pumping crew, using five-gallon back pumps loaded with timbo solution. The back-pumpers on shore were assigned also to give special treatment to all inlet streams, springs, and to the outlet. In addition to treatment with back pumps, it was planned to treat inlet streams *continuously* by staking well up into them small sugar sacks filled with comparatively thin timbo mud.

Nine stations of two men each, for the mixing and supply of chemical and fuel, were planned at strategic locations on shore for the eight open water lanes and for the zone of marginal trolling mentioned above.

A concrete boat-landing on the east side of the lake, in Gull Lake Public Camp, was selected as the central station for fish rescue. From

this point a paved road nearby made it possible for hatchery trucks with aerated fish planting equipment to transport rescued fish rapidly, either to Fern Creek Hatchery or to water suitable for trout lower down in Reverse Creek. Three two-man power boats each equipped with a long-handled dip net, a fish pack can and a galvanized water pail, were assigned to cruise systematically about the lake and to rescue trout as they appeared. When several trout had been gathered in the pack can, they were then to be rushed to the central station and quickly transferred to aerated fresh water on the hatchery truck. Later when the trollers had completed the work of spreading chemical, it was planned to press these units into fish rescue but to rescue only from the zones and lanes originally assigned to them.

All subdivisions and plans, in so far as possible, were located on a large "master" field map of the project drawn nearly to scale. From this map were drawn 50 smaller individual maps for special instruction to personnel assisting in the project.

Organization and Instruction of Personnel

With the exception of assistance from employees of the Division of Fish and Game and from the Mono National Forest (CCC men), the personnel for the chemical treatment of Gull Lake consisted of volunteers from the village of June Lake and vicinity. All the help solicited by the writer was given gladly and with much interest in taking part in the chub removal program.

All persons desiring to help in the project were asked to sign a form headed by the following statement: "I will take part in the project for one day according to plans formulated by the California Division of Fish and Game; I also volunteer the use of such equipment as is needed and such that I have available, provided reasonable care is executed in the use of such equipment." When signatures had accumulated to the point where definite organization could be undertaken, posters were placed announcing meetings of the Gull Lake volunteers to be held at June Lodge in the village of June Lake.

Two meetings of a half-hour each, for organization and instruction, were held at June Lodge and a third, for final instructions and trial of equipment and men, at Gull Lake on the afternoon preceding the major experiment. In the first meeting the following subjects were discussed: A review of Gull Lake with some information on hydrography and lake biology, the rise of the rough fish population and the decline of the Gull Lake fishery, the use of rotenone as a measure for the control of rough fish with examples of its use elsewhere, and tests made by the writer with derris and timbo powders on fish. The latter subject was discussed briefly while a rapid experiment, using timbo powder in a concentration of 1:1,000, was performed with five small chubs from Gull Lake for the benefit of the group.

In the second and more detailed meeting, the volunteers were organized and given thorough instruction in the theory and practice of the major experiment. Men were assigned to teams according to the plans for the experiment. The teams included an open water trolling team of eight men, the marginal trolling and pumping team of eight men, the inshore back-pump team of six men, the mixing team of 18 men, and the fish rescue team, which tentatively consisted of four men.

Leaders were appointed to each team. Mixing of the chemical and the preparation of burlap bags for trolling were discussed. Distribution of the chemical was discussed and much emphasis was placed on uniform distribution.

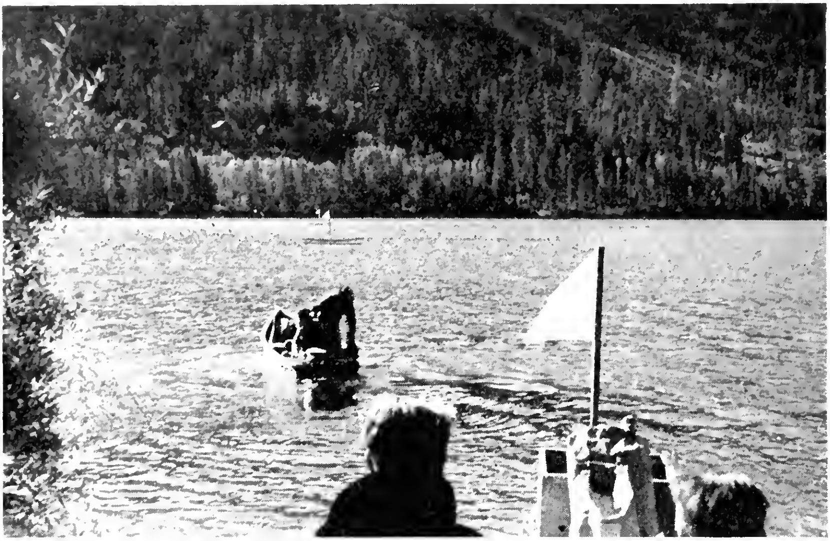

FIG. 14. Open-water trolling of chemical, west to east in lane A; the men are starting out after obtaining re-fill of timbo mud from supply station in foreground. Note flags marking the lanes. Photograph by George S. Myers, September 11, 1940.

In so far as possible the open water trollers were instructed to move abreast in their parallel lanes. In the north-to-south lanes the trollers assigned to the west half of the lake were instructed to begin the distribution on the west side of their lanes and work eastward, whereas the trollers assigned to the east half of the lake were instructed to begin distribution on the east side of their lanes and gradually work westward. In the west-to-east lanes the trollers were instructed to begin the spreading of timbo to the windward (prevailingly south) and work to the lee. Using the project field map, specific plans were reviewed in detail before the group, so that all volunteers would clearly understand the positions assigned. A special meeting was held with the leaders of the several teams and instructions were further discussed with them.

The final meeting, held in the afternoon at Gull Lake, comprised a complete review of the project with teams and leaders, and individual maps with specific instructions for each participant in the project were distributed and explained where necessary. Following the meeting, the teams proceeded to tune up motors and to make trial runs across the lake in the lanes and zones assigned. Individual trollers timed other trollers in complete round trips, from the onshore supply stations to the opposite end of the lanes and return. Due to high wind and a rough lake during the afternoon a complete "dress rehearsal," so

termed by some of the volunteers, was not accomplished. However, the men were given an opportunity to familiarize themselves with equipment and with the various subdivisions of the lake.

Preparation of Gull Lake for Chemical Treatment

Warning Against Domestic Use of Water from Gull Lake

Despite the fact that the experimental work with derris and timbo powders indicated that the concentrations effective against fishes were nonpoisonous to man and higher animals, it was essential to take precautions against the *chance* of susceptibility to the poison. All users of the water for domestic purposes were interviewed two weeks in advance of chemical treatment of the lake. Where necessary the writer made special arrangements during the interviews for users to obtain fresh water from convenient sources elsewhere during the period of restriction on the use of water from the lake. Signatures were obtained from the persons interviewed under the following heading: "We, the undersigned, agree not to use water from Gull Lake for any purpose until notified by the California Division of Fish and Game following the rough fish control project on said lake."

On the day of the Gull Lake experiment, a warden of the Division of Fish and Game posted notices in conspicuous places around Gull Lake notifying the people not to use the water until advised to do so.

Gathering and Arrangement of Equipment

The gathering of properties and equipment loaned for use in the Gull Lake project was carried out over a period of about one month prior to the experiment. Truckers of produce, resort owners, residents of June Lake, the Gull Lake volunteers, sportsmen, Joseph's Market in Bishop, the California Division of Fish and Game, the United States Bureau of Fisheries, the United States Forest Service, and the State Division of Highways at Crestview were the principal sources from which the properties and equipment were gathered.

On the day prior to the major experiment, the full amount of timbo required for the experiment, totaling 3,300 pounds, was transported to Gull Lake from Mt. Whitney Hatchery. Boats, motors and all other equipment, except portable pumping and aeration equipment for fish rescue, were made ready at Gull Lake on the same day. The portable pumping and aeration equipment was at hand early the next day.

Early on the morning of the major experiment quantities of chemical, together with mixing and trolling equipment, were placed at each of the nine onshore supply stations. The mixing equipment consisted of a wooden paddle, a large galvanized wash tub, and two water pails per station. The trolling equipment, in addition to the power boats and accessories, consisted of four burlap sacks, and three lengths of stout cord, each 25 feet long, per station.

Flagging or Marking the Lake

Two days before the project Gull Lake was marked with orange snow stakes obtained from the State Division of Highways. To the top of each stake was attached a triangular flag of yellow cambric. Twelve such conspicuous markers were driven around the edge of the lake.

These, together with nine others fastened upright in rowboats securely anchored fore and aft in the open water, clearly designated the lanes for distribution of chemical (see Figs. 14 and 15). The preparation and placement of flags in the lake required a full day.

Excavation of a Pit for Disposal of Dead Fish

Two days' work with a bulldozer were required by laborers from Mono County to excavate a pit for the disposal of dead fish. The burial site was 25 feet long, 15 feet wide and 4 feet deep, and was located near the north shore of Gull Lake.

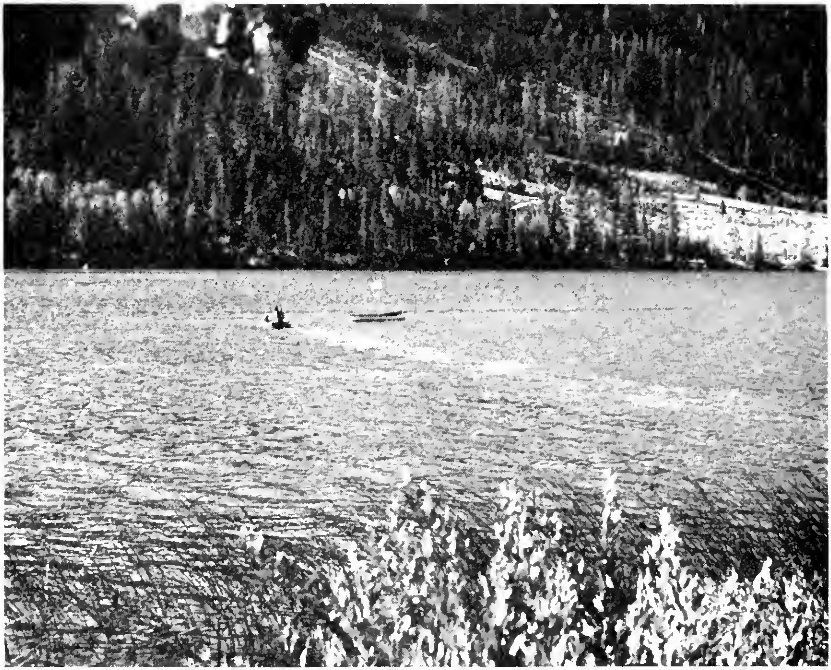

FIG. 15. Open-water trolling of chemical, west to east in lane A; the trollers are about 200 yards out. Note expanding cloud of timbo mud in wake of boat. Photograph by George S. Myers, September 11, 1940.

Closure of Outlet of the Lake

Late in the afternoon of the day before the project, laborers from Mono County completely closed the outlet of Gull Lake, using planking and several truckloads of earth. By the following morning the outlet stream was no longer flowing. This move scarcely affected Reverse Creek below Gull Lake as springs, starting about 120 yards below the outlet, provided a flow adequate for the fish life downstream. The outlet was kept closed for the duration of the period required for natural recovery of the lake and until check screens and dams above and below the lake were installed.

The period of seasonal intermittent flow for the inlet stream, at this time of year obviated a problem with this tributary.

CHEMICAL TREATMENT OF GULL LAKE

Application of the Poison

On September 11, 1940, at 6.00 a.m., all volunteers in the Gull Lake project met with the writer at the north end of the lake. Using the project field map, the team assignments were rapidly reviewed again and some last minute changes in the personnel of some teams were made. Following a demonstration of mixing of the timbo mud and the filling and fastening of a burlap bag of the chemical, teams proceeded to assigned starting places and awaited the signal from the writer to begin chemical treatment. At 8.03 a.m. two shots from a pistol directed all participants in the experiment to get ready and two minutes later a single shot began the chemical treatment of Gull Lake.

Mixing of Chemical on Shore

At each supply station two men mixed chemical for the trollers in the power boats. Early in the mixing the men found it necessary to thicken the timbo mud for the trollers spreading chemical over a longer distance; the troller found that his bag of chemical was exhausted before he had completed a round trip. At first small slits were cut in the burlap bags, but these were abandoned when the timbo mud was found to spread in an excellent manner directly through the wet burlap.

Mixers frequently interchanged from the task of stirring mud to the addition of powder and water; the stirring procedure rapidly became tiresome and fine particles of powder were often scattered toward the face accidentally. The mixers had earlier been cautioned to stand to the windward, while pouring and mixing powder. Even so, three "casualties" were recorded during the day. One mixer, a CCC boy, caused inflammation and profuse watering of his eyes by rubbing his face with hands wet with timbo mud. Cold water and 2 per cent argyrol were copiously applied, and by late afternoon he had fully recovered. Another mixer, similarly affected, recovered by the following morning under similar treatment. A third mixer coughed and suffered from an inflamed throat when he accidentally breathed some of the powder; later he reported a dull headache, possibly resulting from the irritation by the timbo powder. Free gargling with cold water materially hastened recovery by the next day. But with the great majority of mixers and those handling the chemical, no discomfort at any time was reported. Most of these persons frequently washed their hands with water during the experiment.

When all the timbo powder placed at supply stations had been used, mixers washed into the lake any remaining mud and powder that had been scattered about the station during the day.

Open-Water and Marginal Distribution of Chemical

Light brown to buff clouds of timbo extended out behind the boats trolling chemical as they proceeded on their courses. (see Figs. 14 and 15.) Early in the day the open-water trollers found that trolling the bag of chemical alongside the boat on a short cord not over four feet long accomplished better spreading than when the bag was towed at greater length directly in the wash of the propeller behind the boat.

Some trollers used two bags of chemical at a time, fastening them with short lines one on each side of the boat. This method proved exceptionally good when used with a more highly powered outboard motor on the boat.

Although trolling teams, excepting the marginal team, had been instructed to troll chemical at the surface and at 15- and 30-foot levels in their sections, for the most part trolling at the surface was adequate. Deeper trolling was found to be extremely difficult and hazardous and greatly slowed chemical treatment as a whole. Trollers used the 25-pound anchors to troll at the deeper levels. Advance instruction of trollers in securely fastening the trolling lines to bags of chemical before starting prevented the loss of all but one bag of chemical. In that instance the towline had not been securely fastened to the boat before starting out.

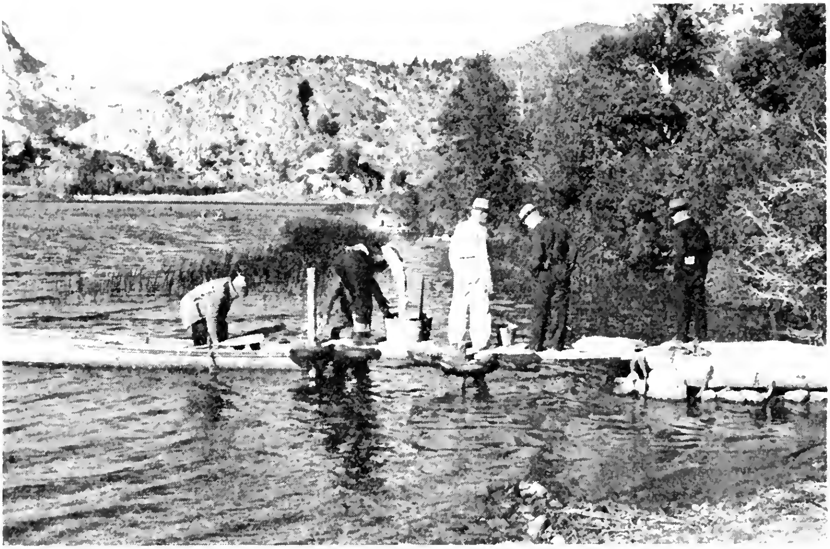

FIG. 16. The marginal troller takes on a re-fill of chemical at the marginal supply station. Note burlap bag of timbo mud ready for spreading and commercial package of timbo powder on pier at right. Open-water trollers and two supply stations are seen in the background. Photograph by George S. Myers, September 11, 1940.

Several open-water trollers combined a zig-zag course with the straight course in trolling chemical in the lane assigned to them; the zig-zag course was overlapped on the return trip across the lake. This method of distribution from all appearances was excellent and strengthened the original contention by the writer that a combination of several ways and means of distribution would best accomplish the desired uniform spreading of the chemical throughout the entire lake.

Where possible, large outboard motors were used to create a greater wash behind boats and to speed up and more thoroughly disperse the timbo mud in the water.

On nearing marginal zones the trollers in the open water lanes made every effort to overlap their spreading of timbo with the team trolling the chemical marginally.

Working ahead of the marginal pumping team was the troller of timbo mud in the marginal zone (see Figs. 16 and 17). Using a 14-foot metal boat, powered by a large outboard motor, a dense cloud of timbo was spread especially well near the thick reed and marsh areas and where small inlets and springs entered the lake. Frequently, the troller would double back several times in front of such critical areas before continuing in the course around the lake. Where possible, the waves and heavy wash produced by the big motor were used to create currents which would carry the chemical deep into the area under treatment.

FIG. 17. The marginal troller returns after a trip around the lake; note large outboard motor used and trolling line extending out behind boat. Open-water trolling of chemical in the background. Photograph by George S. Myers, September 11, 1940.

Streams of treated water shot out from 60 to 90 feet as the portable pumps, in power boats following the marginal troller, rained the heavily treated water deep into the marginal zone (see Figs. 18 and 19). Nothing was left untreated along the margin of the lake by the pumpers and extra streams of the supertreated water were pumped into questionable areas, such as the marshes and small inlets. Use of the portable pump in this manner was continued in overlapping fashion throughout the day in the marginal zone and for some time after 3.30 p.m., by which time the last of the timbo powder at the mixing stations was distributed.

Distribution of Chemical Inshore and in Inlet Streams

A supervised crew of six men equipped with five-gallon back pumps worked in coordination with the marginal troller and pumpers. These men, when not in the vicinity of a mixing station, mixed their own solution in the back-pump reservoir. This was done by filling the reservoir with water and adding about three handfuls of timbo powder, then vigorously shaking the entire contents after replacement of the metal cap. Wearing hip-length gum boots, the back-pumpers treated assigned areas along the shore and gave special treatment well up into the inlet streams and to springs. Small sugar sacks of timbo mud were staked well up into inlet streams and provided continuous treatment of these waters during the experiment. In fact, the springs and inlet streams were given two additional treatments with a back pump by the writer on separate days, immediately following the major experiment. Approximately 50 pounds of chemical were distributed by the crew of back-pumpers.

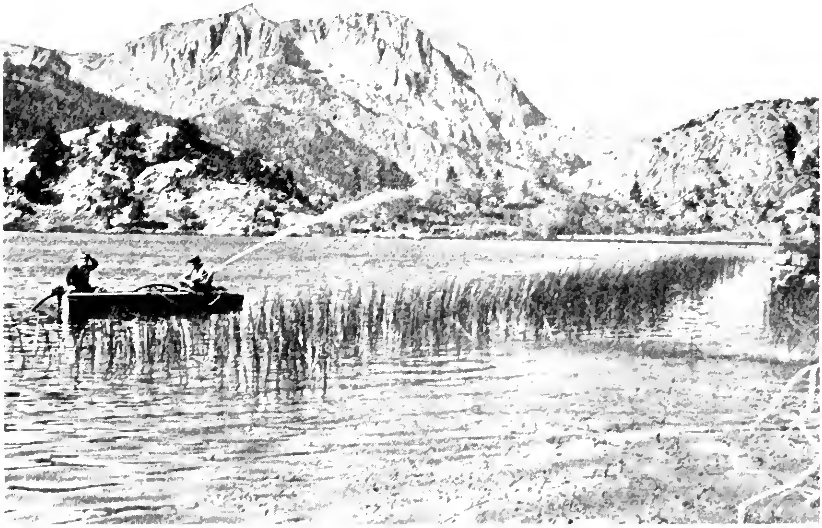

FIG. 18. A marginal pumper rains heavily treated marginal water into a section of aquatic plants and marsh. Note how stream of water and spray reaches the extreme margin of the lake. In such areas thousands of small chubs were killed by this treatment. Photograph by George S. Myers, September 11, 1940.

Results of Chemical Treatment

The first chubs to be effected by rotenone began to appear within 30 minutes after treatment of the lake was begun. These included large numbers of chubs up to one and a half inches long. It was significant that the first fish to be affected were observed near one of the stations for mixing chemical. The fish had already lost equilibrium and were darting in helter-skelter fashion near the surface of the water, frequently flashing their bright sides in the sunlight. In a little over three hours, chubs up to eight inches long were seen darting in crazy fashion among, by this time, literally thousands of

smaller fish. The latter, averaging near three inches long, were overcome and dying as they were drifted toward the north shore of the lake by a light south wind.

By the end of the day, the shores of Gull Lake, particularly the north and east banks, were lined rows deep with dead and dying lake chubs from one-half to nine inches long. No count was made on chubs under two inches (of which shore estimates indicated earlier in excess of 100,000), but of chubs two to nine inches an estimated 392,500 were killed by the chemical treatment. (Estimate was made by sampling 100-foot sections).

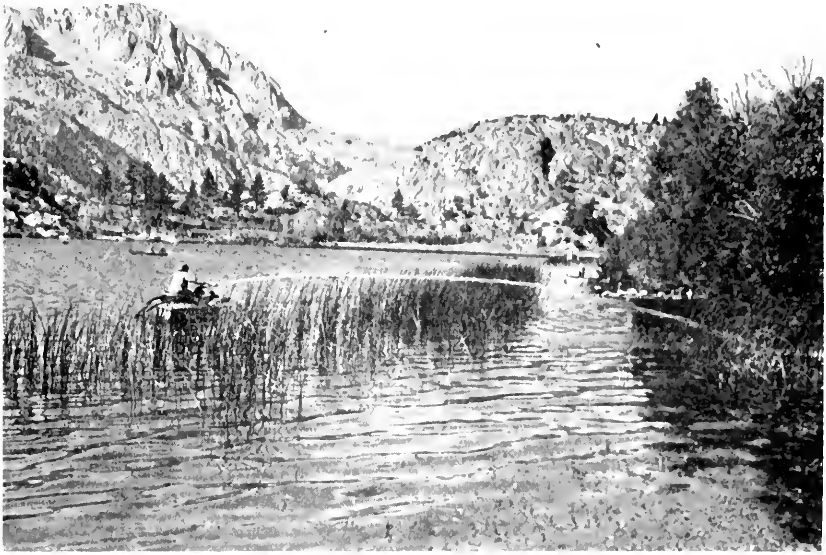

FIG. 19. A marginal pumper repeats treatment of the section shown in Fig. 18. Note open-water trolling in the distance. Photograph by George S. Myers, September 11, 1940.

Some eastern brook trout, following pursuit and capture of the helpless and affected small chubs in the marginal zone, were themselves overcome within the first hour and necessitated fish rescue somewhat in advance of schedule. Trollers of chemical soon afterward reported trout appearing at widely separated points over the lake, and rescue of trout with dip nets from power boats and from shore rapidly got underway. Many trout were rescued by laymen viewing the project along shore and some trout were lost when they were crowded in rescue containers. With the exception of a few, most of the trout rescued were taken in aerated trucks to troughs set aside in Fern Creek Hatchery in which cold, abundantly aerated water soon checked the action of the chemical on the gills. Following their complete recovery, which occurred after several hours, the trout were placed in an exhibition pool at the hatchery for observation. Of a total of 254 trout observed or rescued from Gull Lake, ten were Loch Leven, the remainder being eastern brook. Seventy-eight trout survived to be replanted lower down in the drainage in Silver Lake. It is the writer's belief that

had all trout been rescued entirely by the experienced fish culturists who participated in the experiment, many more rescued trout would have survived.

TABLE 2

Fish Removed from Gull Lake by Poison

Lake chubs under 2 inches	100,000	(estimated)
Lake chubs over 2 inches	392,500	(from counts made of sample shoreline sections)
Chub total	492,500	
Trout, eastern brook	244	
Trout, Loch Leven	10	
Trout total	254	

On the next day, together with Alan C. Taft, Chief of the Bureau of Fish Conservation, Division of Fish and Game, the writer examined a gill net set as the last event in the previous day, and carefully examined the marginal zones of the lake. The gill net contained 45 chubs, all dead. Some appeared as though they had merely drifted into the net and were caught during weak struggle. Around the lake large numbers of dead minnows and a few dead eastern brook trout were seen at various depths. Except for several chubs five to six inches long, belly up and almost dead, no living fish were found. Careful examination deep in reed and marsh areas revealed a number of dead chubs about one-half inch long.

Dead dragonfly and damselfly larvae and enormous numbers of dead leeches were seen.

Scuds, amphipod crustaceans and valuable fish food organisms, of which dozens were seen, seemed to be unaffected by the timbo treatment. Moreover, there was no indication whatsoever, that any plant life in the lake had been affected by the chemical treatment.

Concentration of Timbo Used in Treatment of Gull Lake

From the hydrographic information obtained during the survey of Gull Lake it was found that the lake, at the time of chemical treatment, contained 2,537 acre-feet of water weighing approximately 6,894,-000,000 pounds. The total weight of the timbo powder used in the chemical treatment was 3,300 pounds, hence 0.48 p.p.m. was the concentration of timbo used in the control of rough fish in Gull Lake.

PERIOD OF RECOVERY OF GULL LAKE

Removal of Dead Chubs

During the week following chemical treatment of Gull Lake, dead chubs came to the surface rapidly and light winds sweeping the lake from the south drifted them on shore. Men and equipment loaned by Mono County on September 14 and 17 raked up and hauled to the disposal pit an estimated 4½ tons. Most of the dead chubs, however, were left to decompose in the lake and for a time a noticeable odor from the dead fish was observed. By October 1, 20 days later, there was only a slight odor at various places about the lake, and finely pulverized bits of fish, pounded and broken by winds striking the lake, could

be seen in the water. On the latter date, comparatively few entire fish were to be seen.

Contrary to expectation, few seagulls and other aquatic birds helped to clear Gull Lake of dead fish immediately after chemical treatment. Not until September 23, 12 days after the poisoning, were aquatic birds noticed on the lake in any number. On this date at 2.50 p.m. the writer observed 19 California gulls, at least 12 coots, 2 pied-billed grebes, 3 American egrets and 1 American bittern. Although the gulls and the grebes ate dead chubs, the other birds apparently did not relish the decomposing fish.

Observations and Tests During Natural Recovery

During the three-day period immediately following chemical treatment, three sets with a 125-foot graduated mesh gill net in the deepest part of the lake (60 to 63 feet) failed to reveal any sign of living fish. Examinations in the lake, carefully repeated at intervals, especially in the marginal and inlet areas, also failed to reveal any sign of fish life. On September 15, four days after the poisoning, a committee of sportsmen, George McSweeney, E. T. Mahoney, William A. Abbott, H. A. Wallis, H. Byrnes, and H. P. Burger, headed by Wallace Gerth of June Lake, accompanied the writer in a comprehensive examination of Gull Lake. Special attention was given to marshes and inlet and outlet areas. The lake was found by the group to be devoid of fish life. Gratifying was the discovery of abundant scuds and small damselfly larvae alive and apparently healthy. A gill net, set 19 hours earlier, was drawn before the group and found empty.

Several tests were made on living fish; these are summarized in table 3.

TABLE 3

Tests of Toxicity of Gull Lake Water during Recovery Period

No. of days elapsed since poisoning	Trout used	Method of test	Water temperature, F.	Reactions of fish
3	Rainbow, 2 in. long	Water obtained from depth of 62 feet	49°	Died in 2 hours, 15 minutes
6	Rainbow fry	Water obtained from depth of 62 feet	49.5° (Surface, 60°)	Turned belly up in 1 hour, 17 minutes
12	Rainbow fry	Placed in live car at surface		Died in 1 hour, 50 minutes
26*	Rainbow fry	Placed in live car at surface	52°	Still healthy after 16 days of exposure
28	Eastern brook, 5 fish averaging 4 inches	Placed in live car at surface near marginal zone		4 died after 11 days of exposure, but probably from other causes than poison. Fifth trout survived until all tests were concluded
36	Eastern brook, 5 fish averaging 4 inches	Placed in live car in lake at depth of 55 feet, and moved at intervals to other locations, same depth		Still healthy after 34 days of exposure

* On September 26, fifteen days after poisoning, a southerly gale blew for nearly 24 hours, churning up the lake. Recovery of the lake seemed to take place more rapidly thereafter.

From this table it is evident that by the end of 36 days after poisoning, if not earlier, the water had ceased to be toxic to trout.

As early as October 15, a peculiar drift of green debris was seen along the west side of the lake. The material floated mainly on the surface when the lake was calm and seemed to drift slowly. When the lake was disturbed by wind, the greenish raft of material would become dispersed through the lake and fine particles in suspension were noticed throughout. Close examinations revealed the material to be decomposing timbo powder, and the suspension of trout in live cars in the floating debris indicated it to be exhausted and quite harmless. The maximum accumulation of the timbo powder debris at the lake surface seemed to occur by November 10, when the mass appeared to cover an estimated five acres. From that time on the debris began moving through the outlet and downstream.

FIG. 20. The use of modern fish-planting equipment assured rapid and efficient restocking of Gull Lake from Hot Creek State Fish Hatchery. Photograph by author, November 2, 1940.

Restocking

Prior to restocking of Gull Lake it was deemed advisable to make a small test plant from the hatchery and note the effects of the lake conditions on the experimental trout. This was done on October 24, 43 days after poisoning, when 2,080 eastern brook trout, averaging 1.3 per ounce, were introduced into Gull Lake from Hot Creek State Hatchery. The trout were part of a general lot cultured for restocking the lake. For the next seven days Gull Lake was observed closely and at no time were any of the experimental trout seen affected in any section of the lake. Particularly in the morning and in the evening individual trout were seen to rise to the surface here and there, possibly for surface foods.

Judging mainly from the survival in apparently good condition of the experimental trout and from the appearance of Gull Lake after repeated examinations for food organisms and condition of plant life,

conditions seemed favorable for restocking of the lake on November 1, 51 days after the treatment of the lake with timbo powder. The use of modern fish planting equipment assured completion of the restocking program in four days, from November 1 to 4, in which a total of 76,200 eastern brook (5 inches long), averaging 1.1 per ounce, were planted in the lake from Hot Creek State Fish Hatchery. The day after restocking was begun, the newly planted trout were noticed "working" near the edges of reed beds and marshes in the lake. Repeatedly thereafter, the newly planted trout were noticed all around the lake until December 14, when the lake became icebound for the winter.

Removal of Restrictions on Domestic Use of Water

On the third day following chemical treatment of Gull Lake, the writer, in the presence of two men assisting in the project, drank a pint of the lake water. There seemed to be no bad taste to the water and no ill effect whatsoever was experienced. However, due mostly to the many dead and decomposing fish which littered the shores and drifted about Gull Lake, no use of water from the lake for domestic consumption was allowed for the first seven days. But, following this time

FIG. 21. During the period of lake recovery, permanent barriers were installed above and below Gull Lake to prevent migration of fish to and from the lake. The one here shown is in the inlet of the lake. Photograph by author, November 2, 1940.

restrictions on such use were discontinued. Use of the lake water for drinking purposes was not generally resorted to for about a month following the chemical treatment.

Construction of Permanent Barriers

Midway during the period of natural recovery, plans, excavation and construction of permanent barriers above and below Gull Lake were accomplished. The barriers of reinforced concrete and equipped

with 16-gauge, one-fourth inch mesh screens, were so designed that migration of rough fish into Gull Lake, other than the smallest sticklebacks perhaps, would not reoccur naturally. In designing the barriers, the writer sought to eliminate by means of sufficient vertical drop and an inclined concrete apron on the downstream side, any chance for fish to leap over the dam (see Fig. 21). The screens, in addition, were fitted as closely as possible in the ports of the dams to prevent the possible migration around the ends of the screens of fish moving downstream.

Permanent dams and screens were installed immediately above and below Gull Lake in the inlet and outlet and upstream about one-quarter mile at the outlet of June Lake. Adequate precautions have thus been taken against natural reinfestation of Gull Lake by rough fish. As to their reintroduction by anglers, a new law has been passed which it is hoped will be effective. It reads as follows:

> "Sec. 622. It is unlawful to use for bait or to release or to plant any freshwater or anadromous fish other than trout in any inland or tidal waters or portion thereof in which trout have been planted by the commission or which have been designated and posted as trout waters by the commission; provided, however, that fish other than trout may be used for bait or released in the same waters wherein taken, and they may be planted under a written permit issued by the commission when in its discretion the productivity of trout waters will not be reduced thereby."

FISHING RESULTS IN FIRST SEASON AFTER CHEMICAL TREATMENT

From November 1 to 4, 1940, there were planted 76,200 eastern brook trout in Gull Lake, which averaged 1.1 per ounce (about 5 inches long), in addition to the experimental plant of 2,080 eastern brook on October 24, 1941. The lake was opened to fishing on May 30, 1941. The catch as recorded at the only boat concession on the lake is shown in table 4.

TABLE 4

1941 Gull Lake Catch from Rented Boats Only

Month	No. of boat records	No. of anglers	Total hours fished	No. of Eastern Brook caught	Average catch per angler-day	Average catch per angler-hour
May 30-31	24	61	228	133	2.2	0.6
June	35	81	309	480	5.9	1.6
July	91	210	962	1,249	6.0	1.3
August	157	296	911	984	3.3	1.1
September	68	100	437	706	7.1	1.6
October	4	5	32	97	19.4	3.0
Totals	379	753	2,879	3,649	4.8	1.27
Data from incomplete records showing catch but not anglers: Season	115			1,464		
Total recorded catch				5,113		

The table shows a total of 5113 eastern brook trout caught from rented boats. Observations indicate that the shore catch was between

two and three times as great as the boat catch. Seven fishermen are known to have caught 1,400 trout between them during the course of the season. It is safe to estimate that the total catch of trout from Gull Lake during 1941 was at least 10,000 and may have approached 15,000.

Growth of the fish in Gull Lake is shown by the following measurements, made on fish caught in gill nets on the dates recorded:

Date	*No. of fish*	*Average length*	*Average weight*	*Condition factor*[2]
May 5, 1941	19	179.5 mm. (ca. 7 in.)	48.1 gm.	0.83
Nov. 7, 1941	26	195.1 mm. (ca. 7¾ in.)	76.5 gm.	1.014

Increase in length was not great. This can be attributed to two factors. In the first place, the fish were very thin in May, after a long hard winter; food consumed during the season had to go largely toward restoring them to their normal weight rather than to increasing their length. And, in the second place, it is probable that, as often happens, the larger fish were caught first, leaving behind the fish which were too small to enter the catch in the early part of the season. These played only a small part in the May averages but a large one in the November averages. The increase in condition factor and in weight shows the true nature and extent of the growth during 1941.

The final test of the success of the Gull Lake operation is found in the quality of the fishing. June Lake is recognized as a good fishing lake—well above the average, drawing thousands of anglers from distant points in the course of a season. The two lakes are compared below:

1941 Average Catches in June Lake and in Gull Lake

	Average catch per angler-day	*Average catch per angler-hour*
June Lake	3.1	0.56
Gull Lake	4.8	1.27

Furnishing the angler with trout, in its first season after poisoning, at an hourly rate over twice as great as obtained in June Lake, Gull Lake can be said to have handsomely justified the time and money spent in reclaiming it from rough fish.

[2] Condition factor is a term used to express the relation between the weight and the length of a fish. It is calculated as follows:

$$\text{Condition factor} \quad \frac{\text{Length in grams}}{(\text{Weight in centimeters})^3} \times 100$$

Fish in good shape usually have a condition factor of about 1.0

APPENDIX

Materials and Equipment Used

In the course of the Gull Lake experiment a considerable variety of materials and equipment was used. In the compilation of such items for the present report these were divided, according to the purpose for which used, into several categories as follows:

A. Publicity and Instruction
1. Posters, announcing closure of lake.
2. Individual outline maps and directions for teams and participants in the project.
3. Key map showing plan of entire project.

B. Marking of Lake
1. Flags of yellow cambric.
2. Orange snow stakes from State Highway Maintenance Station at Crestview.
3. Rowboats for use with flags and stakes as markers in open water.
4. Necessary anchors, anchor rope, stay lines, etc.

C. Closing Outlet of Lake
1. 1 dump truck for half a day and 5 cubic yards of earth.

D. Distribution of Chemical
1. Mixing of chemical on shore. At each of the nine mixing stations were located: 1 large galvanized washtub; 2 galvanized water pails; wooden mixing paddle; 4 burlap sacks and extras as needed; 3 lengths of heavy cord (each 25 feet) for use in trolling burlap bags of chemical; and apportioned amounts of timbo powder totaling 3,250 pounds.
2. Open-water trolling of chemical. Items included: 8 each of rowboats; twin outboard motors and fuel cans; anchors for deep trolling; and sets of oars for emergency.
3. Marginal trolling of chemical. Items included: a large rowboat; a four-cylinder outboard motor and fuel can; and a set of oars for emergency.
4. Marginal pumping of chemically treated water. Items included: 3 motorized, portable pumps; short suction and discharge lines; and adjustable nozzles for spraying treated marginal water into marsh areas and small marginal spring inlets; 3 launches with twin outboard motors for use with portable pumps (such boats were used to lessen the danger of capsizing when employed with the portable pumps and to provide ample room for two-man operation); 3 sets of oars for emergency use.
5. Inshore and inlet stream distribution of chemical. Items included: 10 back pumps, 5-gallon capacity, of U. S. Forest Service type; 5 pairs rubber boots, hip size; 1 dozen 5-pound sugar sacks for stationary placement of timbo mud in springs and small inlet streams to insure constant treatment, supplementing back-pump treatment; 24 feet binding cord in 2-foot lengths, for fastening small sacks of timbo mud; 1 dozen stakes, used in staking the small sacks of chemical; and 50 pounds timbo powder.

E. Fish Rescue. Items included: 1 forty-can aerated fish-planting truck; 1 aerated pick-up fish-planting truck; 4 fish-planting buckets; 2 six-foot hand sienes; 2 pairs gum boots, hip length; at least 25 short-handled dip nets; 3 rowboats; 3 outboard motors; 3 sets oars for emergency use; 3 sack-covered pack cans of type used by California Division of Fish and Game in back country fish-planting.

F. Removal of Dead Lake Chubs. Items included: Long-handled shovels; garden rakes; a 30-horsepower caterpillar tractor with bulldozer, for excavation of disposal pit near Gull Lake; a dump truck; and a short-handled dip net.

G. Construction of Permanent Barrier Screens at Inlet and Outlet. Items included: 14 sacks cement, with necessary sand-reinforcing, concrete mixer, forms and tools; ¾-inch hardware cloth for screens.

H. Miscellaneous: Gasoline; oil; tools; metal tags and crayon for marking equipment for identification.

Cost of Experiment

As the great majority of materials and equipment used in the Gull Lake rough fish control experiment was borrowed and most of the assisting personnel was volunteer, it is difficult to estimate the exact cost of the experiment. Consequently, the following table contains both actual and estimated costs.

Actual and Estimated Costs in Gull Lake Rough Fish Control Experiment

Item	*Amount*	*Cost*
Actual Costs:		
Timbo root powder	3,300 lbs.	$769.99
Oil, grade 40, quart cans	6 gals.	4.94
Gasoline	100 gals.	13.93
Yellow cambric for flags	10 yds.	1.03
Binding cord	400 ft.	2.32
Cement for permanent barriers	14 sacks	11.54
Galvanized wire screen, 16 ga. ¼″ mesh	48 sq. ft.	14.40
Eight-penny common nails	7 lbs.	.72
Hauling of form lumber for concrete barriers	4 man and truck hrs.	3.00
Estimated Cost of Contributions in Kind:		
Men at average of $5 per day	45	225.00
Rowboats, anchors, chains, etc., 1 day	18	36.00
Outboard motors and accessories, 1 day	11	27.50
All other equipment, rental, 1 day		50.00
Estimated total cost		$1,160.37

Editorials and Notes

INTRODUCTION OF EXOTIC ANIMALS

Nowhere on earth are the fauna and flora the same as they were a hundred years ago, thanks to the activity of man. Not only does man destroy, as witness widespread deforestation and the extinction of many animals, but he introduces new plants and animals into the areas where his own migrations take him.

The Pacific Coast States have been particularly blessed—or cursed—with importations of exotic plants and animals, some accidental, many deliberate. The Spanish padres brought with them domestic animals which soon "went wild," and their garden and grain seeds contained the seeds of many European weeds which are now a familiar part of the western landscape. Ever since then we have had many liberations of exotic mammals, birds and fishes.

Perhaps most notable of the introductions to the West have been the importations of foreign and eastern fishes. Except for trout and salmon there were originally very few useful food and game fishes in western streams and lakes. To remedy this scarcity many plantings of exotic fishes have been made, starting about 1870. Some of these were

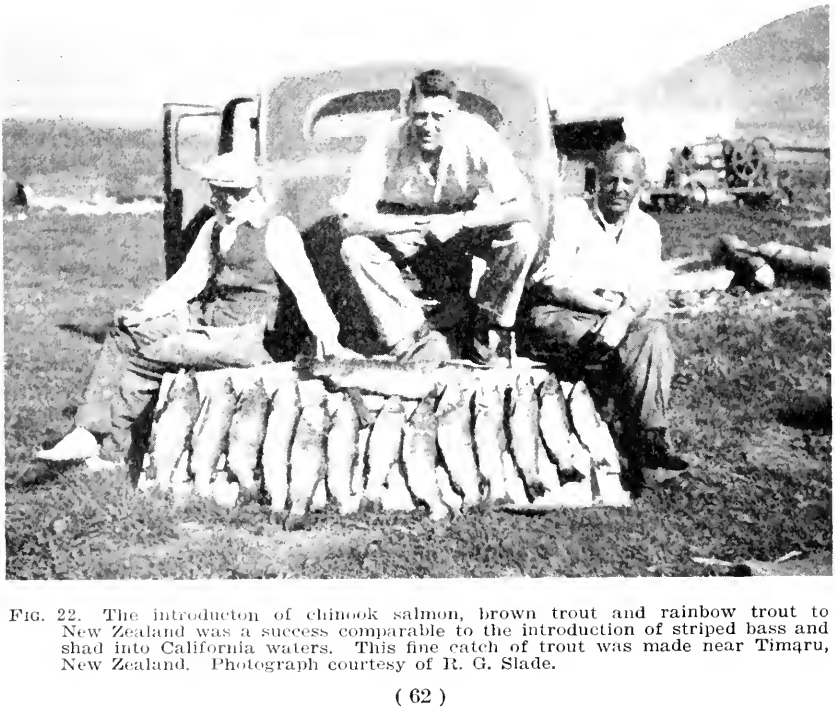

FIG. 22. The introducton of chinook salmon, brown trout and rainbow trout to New Zealand was a success comparable to the introduction of striped bass and shad into California waters. This fine catch of trout was made near Timaru, New Zealand. Photograph courtesy of R. G. Slade.

highly successful, perhaps too successful for the good of certain valuable native fishes. Because of the great interest in these introductions and in view of continued requests for further importations, members of the Western Division of the American Society of Ichthyologists and Herpetologists decided that a thorough discussion of fish plantings would clarify the issue. Consequently, a symposium on the subject was held in Pasadena, California, on June 18, 1941, under the auspices of the society. The history, extent, value and dangers of introductions to Pacific Coast States were discussed in five papers prepared by outstanding fisheries biologists. The papers presented were deemed worthy of a wider audience and four of them are presented in this issue of "California Fish and Game" by special arrangement with the society. Publication of the fifth, on the history of fish introductions in California, has been delayed because the author has uncovered some new facts which require further verification. This article will appear in an early issue.

As proof that some introductions have been too successful, we can refer the reader to another article in this issue—on carp control work in Lake Almanor. The carp is probably the most unpopular of all our introduced fishes and control of this overabundant fish is a real problem in California.

Transplantation of fish from one drainage system to another is also attended with dangers. Fishermen often carry live bait with them, in ignorance of the laws that forbid such action, and undesirable fishes become established in waters formerly free of them. The article on rough fish control in Gull Lake, which appears in this issue, shows how much trouble such transplantings can cause.

Because of the dangers attendant on promiscuous introductions, California laws forbid all unsupervised shipments of live animals into the State. However, many species of birds, mammals and invertebrates have entered the State in the past and have become established.

The California fauna contains a long list of exotic mammals, virtually all introduced accidentally or at least by unauthorized persons. Among the first to arrive were the domestic goats and pigs, which now run wild and furnish considerable hunting on the islands off southern California and in the Coast Range. Other early arrivals were the brown rat, black rat, roof rat and house mouse, and unwelcome arrivals they were. Possums are now found in many parts of the State and the European boar has become established in parts of the central Coast Range. Many wild burros, progeny of those that have escaped from prospectors, roam our deserts where they are endangering the bighorn sheep by despoiling water holes and overgrazing. Perhaps the most amusing liberation was the release of the camels once employed to carry mail over the deserts. However, these animals failed to become established. Aided by many transplantings, the muskrat, which was native only to restricted localities on the eastern edge of the State, is now abundant in many parts of California.

The California Division of Fish and Game has made efforts to introduce various kinds of old-world game birds into California. Several kinds of pheasants, particularly the ring-necked variety, are abundant enough to provide good shooting in certain localities. The chukar partridge is gradually becoming established also, particularly in the wilder,

more barren mountains of the south. The Hungarian partridge has failed to adapt itself in California, although it does well in other western States. Two other species of foreign game birds are to be found in California—the ring dove and the Chinese spotted dove. Both birds have escaped or have been liberated from aviaries and are abundant in suburban areas of southern California. Most common and most heartily disliked of the foreign birds is the European or English house sparrow, which is apparently here to stay in spite of sporadic efforts at eradication.

The bullfrog of the eastern and southern States is now common in the lowland waters of California and furnishes food and sport to many people. A Japanese salamander is also to be found in the wild state in the Sacramento Valley.

Many efforts have been made to establish Atlantic and Japanese oysters in California but all have failed; it is still necessary to import the spat annually. However, Japanese oysters now reproduce to a limited extent in the Puget Sound area. The Atlantic soft-shell clam was accidentally introduced to San Francisco Bay with shipments of eastern oyster spat many years ago. The clams thrived where the oysters did not, crowding out native clams, and soon were abundant enough to support a fair sized industry which still exists. Of great importance to agriculturists, foresters and gardeners are the many foreign insect pests that have found their way into the State. The Atlantic oyster drill is another unwelcome "foreigner." But to most of us the most heartily detested alien of all is the common garden snail, which was once imported from Europe by people who wished to supplement a barbaric western diet with this old-world delicacy.

Thus, it can be seen from this partial list that, for better or worse, we have with us to stay a host of exotic animals of all kinds. From the highest mountains out into the ocean we can see the effects of man's inclination to tinker with Nature.—*Richard S. Croker, Editor, California Fish and Game.*

TWENTY-FIVE YEARS AGO IN "CALIFORNIA FISH AND GAME"

The leading article of the January, 1917, issue of "California Fish and Game" was the "History of the introduction of food and game fishes into the waters of California," by W. H. Shebley, who was for many years in charge of California's fish-cultural activities. This article, similar in its subject to several articles in the current issue, lists the various kinds of fish that had been introduced into California, the dates of introduction in so far as they could be ascertained, and the success of the introductions. The liberation of striped bass, shad, black bass, catfish and other species was very successful and has been the subject of much discussion and study by fisheries biologists. However, as these fish seem so much at home in our waters, most fishermen assume they are native and it is part of the purpose of Shebley's article, as well as those in the current issue, to acquaint fishermen with the story of these introductions and their results.

Other articles told of nature study in public schools, trout hatchery operations during 1916, the food of roadrunners, and many other

subjects. A summary of the Twenty-fourth Biennial Report (1914-1916) of the California Fish and Game Commission was included. During that biennium, 783,000 acres of game refuge were created. The Department of Commercial Fisheries and the Bureau of Education, Publicity and Research were established and studies of the State's fish and game resources were conducted. During 1915 bounties were paid for 162 mountain lions and during the first six months of 1916 payments were made on 111. Sixty-eight deputies carried on patrol work. Sufficient fish were liberated from the hatcheries to furnish every resident of the State with 16 fish. It was also during the 1914-1916 biennium that "California Fish and Game" was founded.—*Richard S. Croker, Editor, California Fish and Game.*

STRIPED BASS SPAWNING AREAS IN CALIFORNIA

During the course of the study of the downstream migration of salmon as a part of the Central Valley fisheries investigation by the California Division of Fish and Game, opportunity was afforded for continuing the search for striped bass spawning grounds. Free striped bass eggs were taken during the middle of May, 1940, in several localities in the lower Sacramento-San Joaquin Delta region: Piper Slough, Three Mile Slough, and in the San Joaquin River between Three Mile Slough and the Big Break.[1] These egg samples constitute the first definite information as to the spawning areas of this species in California. The eggs were collected at night in set plankton nets and, with but few exceptions, within four or five feet of the bottom. The eggs were approximately 12 hours old when taken.

At no time were the eggs taken in abundance, which may indicate that the major spawning areas are to be found elsewhere or that the main spawning season occurs somewhat earlier in the year.

The habitat in which these eggs were found differs markedly from the known spawning areas of this species on the Eastern Coast. The sloughs of the Delta are simply waterways between reclaimed tracts of land, bounded on either side by tule-covered levees. For several feet above the bottom, a mass of decayed vegetable matter, or peat, is suspended and the water is murky at all times. Except during periods of high water, the only water movements are those caused by the tides. Pearson[2] states: "It appears probable that the most important spawning ground for this species, at least along the Atlantic Coast, is in the upper Roanoke River, where there occurs a fall of 50 feet in about six miles and that in the rapids, where the current is exceedingly strong and rendered erratic by islands, boulders, and rocks, the striped bass prefers to spawn."

The water at the point where the eggs were taken and for nearly 15 miles downstream was strictly fresh; the temperatures encountered ranged between 66° and 68° F.—*S. Ross Hatton, Bureau of Marine Fisheries, California Division of Fish and Game, November, 1941.*

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[1] The author is indebted to Mr. John C. Pearson, of the United States Fish and Wildlife Service, for identification of the eggs collected.

[2] Pearson, John C. The life history of the striped bass, or rockfish, *Roccus saxatilis* (Walbaum). United States Bureau of Fisheries. Bulletin, vol. 49, no. 28, pp. 825-851, 1938.

THE 1941 PISMO CLAM CENSUS

The annual census of Pismo clams (*Tivela stultorum*) on Pismo Beach was taken on November 17 and 18, 1941, by staff members of the Bureau of Marine Fisheries, California Division of Fish and Game. The survey disclosed that for the fourth consecutive year the set of young clams was negligible. Further, the total number of clams found was the lowest in many years.

Older clams, particularly survivors of the successful 1935 set, remain fairly abundant on that portion of the beach closed to digging. Though virtually no clams under six years of age were found there, the situation does not seem unduly serious. It should be a matter of years before the existing reserve of adult clams diminishes to a dangerously low level, and records of past years indicate that a fair set is likely to occur before that level is reached. This assumes that the area will remain closed and that adequate patrol will continue. Meanwhile, it is apparently fulfilling its function of preserving a supply of mature individuals.

On the portion of the beach where digging is permitted, different conditions prevail. There is no reservoir of older clams similar to that found in the closed area. Most of the clams reaching legal size are removed immediately; the 1935 year-class is now virtually gone. A good set occurred in 1937, but it suffered an unusually high mortality and clams of that year are now rare. This, combined with the succession of poor sets, precludes any sizeable addition to either the mature (over three-years old) or legal-sized groups for several years to come. Years ago the intertidal zone, in which the census is made, was the region of greatest abundance. Now diggers find it necessary to go into waist-deep water on a very low tide in order to find any numbers of large clams.

It must not be assumed that the clam population is beyond recall because of its present low ebb. In the mid 1920's, unsuccessful sets were likewise the rule and the number of spawners was greatly reduced. Further, the area now closed was not restricted at that time. Despite all this, a series of good sets followed and clams became relatively abundant for a few years. The possibility of a heavy set or sets then remains and with it the chance of at least temporary natural repopulation under existing conditions. To bring about permanent improvement, it may be necessary to introduce legal measures. One which has received consideration is closing and opening sections of the beach alternately, thereby allowing the population to build up in one section and then be removed while another area is given protection. A more drastic measure, which may yet prove necessary, would be the prohibition of commercial digging or possibly even the complete closing of the beach for a period of years.—*Phil M. Roedel, Bureau of Marine Fisheries, California Division of Fish and Game, November, 1941.*

Reviews

Return to the River: A Story of the Chinook Run

By Roderick L. Haig-Brown; illustrated by Charles De Feo. New York, William Morrow & Co., 1941. 250 pp., 16 illus., map. $3.00.

Although written with the narrative skill and suspense that is found in a good novel, this biography of the chinook salmon is not only accurate but contains more information about the chinook than any other one book, including strictly scientific papers. Not only is it the story of the salmon, told as it has never been told before, but it is also the story of the food on which the salmon lives, from its early life in the river to the long ocean years; the birds, the fish and the mammals which prey on the salmon throughout its life; the hazards of seaward migration through polluted water, past open ditches and over dams; and the return through the gauntlet of nets and dams and hatchery racks. This is no Peter Rabbit kind of book, however; the conversation is left up to the human bystanders as they watch the salmon. *Return to the River,* although written with the vividness and conviction of an eyewitness to the salmon's life from beginning to end, is rather hazy about the numbers of eggs usually produced by the salmon, especially those of the Columbia, which is the scene of the book. The 10,000 eggs mentioned is almost twice the average for Columbia River fish. The illustrations are a bit too stylized for this reviewer's taste, and the pectoral fins seem undersized in all the drawings. But these are minor defects; this book deserves a place in the library of every reader of "California Fish and Game," not only for its fine handling of a difficult subject but for its timeliness, for this is not a sentimental lament for the great runs of the chinook as they once were—it is the story of the salmon today on the Columbia, the ladders of Bonneville and the work at Grand Coulee. The author evidently believes that the restoration of ladders on little dams and the installation of efficient screens are the best things that can be done and offer more hope than salvage by hatcheries and transfers. Certainly this will have to be done in California to offset the loss of spawning grounds behind Shasta and Friant dams, spawning grounds to which more than 170,000 chinooks migrated during 1940.—*Joel W. Hedgpeth.*

A Field Guide to Western Birds

By Roger Tory Peterson. Boston, Houghton Mifflin Co., 1941. 240 pp., illus. $2.75.

Long awaited by western ornithologists and nature lovers, Peterson's *Field Guide to Western Birds* has been published and by this time many well-worn copies have accompanied their owners through the fields and mountains of the West. For this is actually a field guide, to be taken into the field and used for identifying birds seen but not collected. It is so designed as to simplify sight-identification

and is for the use of beginners and experts alike. It was planned as a supplement to existing bird books and is not intended to replace more pretentious volumes.

This book is the counterpart of the same author's *Field Guide to the Birds,* which covered the birds of the eastern United States. The *Guide to Western Birds* includes the birds to be found from the Rocky Mountains to the Pacific as well as those along the western edge of the Great Plains and in western and southern Texas.

The illustrations are the most important part of the book. The author recommends using them as the primary guide and suggests referring to the text only to ascertain what features to look for in the drawings and to verify the identifications. The drawings show birds in typical situations—flying, sitting on the water, perching—and in male, female, juvenile, summer and winter plumages. Where color plays a part, colored drawings are presented. With these pictures, almost any one can identify any bird he encounters.

Subspecies, of which there is a multitude in the West, are treated in a novel way which should meet with much approval. Only those subspecies which can be readily identified by sight are included in the text and illustrations; the ranges given are for the species as a whole. All the confusing subspecies are listed at the back of the book, along with their ranges. There is a complete index of common and scientific names.

This book should be in the hands of every Western bird lover.—*Richard S. Croker, Editor, California Fish and Game.*

REPORTS

STATEMENT OF REVENUE

For the Period July 1, 1941, to September 30, 1941, of the Ninety-third Fiscal Year

Revenue for Fish and Game Preservation Fund:		
License revenue:		
1941 series—		
Angling	$323,538 50	
Hunting	177,218 50	
Commercial hunting club	125 00	
Commercial hunting club operator	20 00	
Trapping	164 00	
Fish packers and wholesale shellfish dealers	735 00	
Deer tags	63,235 00	
Fish tags	1,337 01	
Game tags	97 89	
Market fishermen	32,830 00	
Fishing party boat permits	114 00	
Fish breeders	15 00	
Game breeders	85 00	
Game management	170 00	
Game management tags	53 04	
Kelp licenses	10 00	
Total 1941 series		$599,747 94
1940 series—		
Angling	$868 00	
Hunting	8,537 00	
Fish packers and wholesale shellfish dealers	5 00	
Deer tags	399 00	
Market fishermen	100 00	
Total 1940 series		9,909 00
Total licenses, 93d fiscal year		$609,656 94
Other revenue:		
Court fines	$13,381 58	
Fish packers tax	54,991 07	
Kelp tax	188 69	
Miscellaneous	1,128 85	
Salmon packers tax	7,364 77	
Total other revenue		77,054 96
Total revenue, 93d fiscal year		$686,711 90
Prior year, 92d fiscal year:		
1941 series revenue	$2 00	
1940 series revenue	—01	
Fish packers tax	—54 74	
Miscellaneous revenue	01	
Total prior year, 92d fiscal year		—$56 74
Grand total revenue all years, Fish and Game Preservation Fund		$686,655 16

STATEMENT OF EXPENDITURES

For the Period July 1, 1941, to September 30, 1941, of the Ninety-third Fiscal Year

Function	Salaries and wages	Materials and supplies	Service and expense	Property and equipment	Total
Administration:					
Demolition of exposition exhibits		$57 54	$29 65		$87 19
Education and public information	$416 66				416 66
Executive	833 32	37 76	1,337 87		2,208 95
Exhibits	66 60	53 32	62 71		182 63
Fish and game magazine		536 96			536 96
General office	2,803 30	222 14	7,361 53	$6 44	10,393 41
Library	540 00		5 50	45 40	590 90
Total Administration	$4,659 88	$907 72	$8,797 26	$51 84	$14,416 70
Patrol and Law Enforcement:					
Cannery inspection	$3,313 10	$141 03	$415 43		$3,869 56
Executive	3,935 00	58 42	679 23		4,672 65
General office	1,811 32	3 25	131 69		1,946 26
Junior patrol	780 00	4 85	149 98		934 83
Land patrol	67,937 23	4,983 35	15,136 59	$968 05	89,025 22
Marine patrol	23,832 87	3,096 58	11,405 04	551 65	38,886 14
M. V. **Bluefin** galley		—147 70			—147 70
Pollution patrol	3,960 00	440 35	1,252 60	3 07	5,656 02
Total Patrol and Law Enforcement	$105,569 52	$8,580 13	$29,170 56	$1,522 77	$144,842 98
Marine Fisheries:					
Central Valley water project study	$1,388 36	$243 78	$922 51	$33 40	$2,588 05
Executive	1,875 00	23 24	120 72	20 52	2,039 48
Field supervision	610 00	7 70	127 85		745 55
Fish cannery auditing			599 02		599 02
General office	2,839 20	19 92	49 78		2,908 90
Research and statistics	15,619 69	363 80	2,081 61	235 89	18,300 99
Total Marine Fisheries	$22,332 25	$658 44	$3,901 49	$289 81	$27,181 99
Fish Conservation:					
Biological survey	$2,840 00	$109 91	$454 03		$3,403 94
Executive	2,685 00	17 86	201 24		2,904 10
Field supervision	1,638 39	72 16	328 92		2,039 47
Fish food unallocated		4,754 97	941 73		5,696 70
Fish planting	994 35	208 80	1,785 38	$8 63	2,997 16
Fish rescue	4,220 81	94 80	1,055 87	1 13	5,372 61
General office	1,785 00	2 80	5 25	2 39	1,795 44
Pollution inspection	1,425 00	32 78	139 53		1,597 31
Statistical	645 00		226 00		871 00
Structural maintenance	600 00	42 46	269 37		911 83
Alpine Hatchery	724 80	80 04	56 30	—2 32	858 82
Arrowhead Lake Egg Collecting Station	2,115 00	105 47	199 32	20 87	2,440 66
Basin Creek Hatchery	1,293 88	135 24	607 15		2,036 27
Bear Lake Egg Collecting Station	530 00				530 00
Black Rock Springs Ponds	182 40	98	13 07		196 45
Blue Lakes Egg Collecting Station	166 67	12 18			178 85
Brookdale Hatchery	1,930 93	427 88	135 73		2,494 54
Burney Creek Hatchery	1,240 00	68 45	124 94		1,433 39
Central Valleys Hatchery	695 97	58 42	231 44	92 21	1,078 04
Copco Egg Collecting Station		4 08			4 08
Cottonwood Lakes Egg Collecting Station	153 22		108 25		261 47
Experimental Hatchery	440 00				440 00
Fall Creek Hatchery	2,040 00	143 58	47 01	2 47	2,233 06
Feather River Hatchery	1,400 00	84 54	210 71	11 10	1,706 35
Fern Creek Hatchery	534 85	15 31	61 43		611 59
Fillmore Experimental Station	867 91	44 37	82 88	3 62	998 78
Fort Seward Hatchery	912 26	74 47	151 42		1,138 15
Hot Creek Hatchery	1,680 00	326 54	191 76	79 83	2,278 13
Huntington Lake Hatchery	1,095 48	114 28	424 50	126 54	1,760 80
Kaweah Hatchery	690 23	114 84	431 31	3 50	1,239 88
Kern Hatchery	785 27	29 93	208 73	4 49	1,028 42
Kings River Hatchery	1,154 52	34 57	1,106 48		2,295 57
Klamathon Egg Collecting Station	238 71	115 39			354 10
Lake Almanor Hatchery	1,896 45	30 59	194 84		2,121 88
Madera Hatchery	557 42	12 77	518 13		1,088 32
Mt. Shasta Hatchery	12,181 44	1,313 11	1,533 90	1 85	15,030 30
Mt. Tallac Hatchery	1,238 71	154 84	112 74	9 84	1,516 13
Mt. Whitney Hatchery	4,129 74	411 41	670 97	43 83	5,255 95

STATEMENT OF EXPENDITURES—Continued

For the Period July 1, 1941, to September 30, 1941, of the Ninety-third Fiscal Year

Function	Salaries and wages	Materials and supplies	Service and expense	Property and equipment	Total
Fish Conservation—Continued:					
Prairie Creek Hatchery	$1,498 61	$200 78	$209 55		$1,908 94
Rearing Reservoir	1,672 42	79 31	230 74	$6 03	1,988 50
San Lorenzo Egg Collecting Station		79 05	12 43		91 48
Sequoia Experimental Station	768 67	13 62	62 31	68 77	913 37
Shasta River Egg Collecting Station	130 00				130 00
Snow Mountain Egg Collecting Station			4 00		4 00
Tahoe Hatchery	2,385 00	165 24	204 48		2,754 72
Waddell Creek Station	450 00		56 65		506 65
Yosemite Hatchery	1,582 80	272 63	134 78		1,990 21
Yuba River Hatchery	990 00	67 03	93 25		1,150 28
Total Fish Conservation	$67,186 91	$10,127 48	$13,838 52	$484 78	$91,637 69
Engineering:					
Engineering	$3,407 93	$203 75	$994 91	$31 68	$4,638 27
Executive	1,140 00	1 16	66 96		1,208 12
Fish screens	240 00	162 10	34 36		436 46
General office	280 00	5 04	6 05		291 09
Total Engineering	$5,067 93	$372 05	$1,102 28	$31 68	$6,573 94
Game Conservation:					
Duck rescue	$623 33	$20 91	$106 62		$750 86
Elk refuge	480 00	82 95	61 03		623 98
Executive	2,445 00	43 12	252 84	$850 00	3,590 96
Game management	3,327 42	364 08	512 15	675 01	4,878 66
General office	995 00	91	740 00	6 13	1,742 04
Grey Lodge Refuge	1,320 00	188 67	20 16		1,528 83
Imperial Refuge	620 00	10 03	27 53		657 56
Los Banos Refuge	992 01	44 80	116 03	9 97	1,162 81
Predatory animal—lion hunting	1,650 00	204 03	1,092 41		2,946 44
Predatory animal trapping	8,441 12	407 40	1,296 52	92 77	10,237 81
Research	1,748 97	178 61	208 55	81 48	2,217 61
Statistics	475 00	126 86	223 48		825 34
Suisun Refuge	821 72	34 27	63 74		919 73
Total Game Conservation	$23,939 57	$1,706 64	$4,721 06	$1,715 36	$32,082 63
Game Farms:					
Executive	$960 00		$205 16		$1,165 16
Game bird distribution—					
Los Serranos	938 06	$93 08	289 13		1,320 27
Yountville	4,038 39	1,131 78	657 69		5,827 86
Game management	360 00		67 26		427 26
General office	285 00		6 96		291 96
Los Serranos game farm	3,151 94	75 26	390 55	$22 91	3,640 66
Yountville boarding house	359 77	112 11			471 88
Yountville Game Farm	3,242 78	1,626 67	682 62		5,552 07
Total Game Farms	$13,335 94	$3,038 90	$2,299 37	$22 91	$18,697 12
Licenses:					
Executive	$960 00	$13 04	$22 50		$995 54
General office	420 00	15 10	7 93		443 03
License distribution	3,860 00	288 80	23,807 38	$55 72	28,011 90
Total Licenses	$5,240 00	$316 94	$23,837 81	$55 72	$29,450 47
Grand total, excluding special support items					$364,883 52

FISH CASES

July, August, September, 1941

Offense	Number arrests	Fines imposed	Jail sentences (days)
Abalone: No license, overlimit, undersized red abalones	29	$545 00	
Angling: No license, closed district, fail to wear license in visible position, fail to show license on demand, closed waters, overlimit, making false statement to obtain license, fish with more than one rod and line, angling more than 2 rods, within 150 ft. of lower side of dam	153	1,605 00	15
Albacore: Selling undersized	1	50 00	
Barracuda: No license	2	50 00	
Bass: Taking striped bass after sunset, undersized, selling striped bass, no license, take with more than 1 rod and line, black bass, no license	103	1,570 00	135
Catfish: Closed season	1	25 00	
Clams: Taking jackknife clams, no license, undersized Pismo clams, overlimit razor clams, Pismo clams, closed season, District 9, undersized cockle clams	48	850 00	212½
Commercial fishing: No license	59	460 00	137½
Crabs: Closed season, undersized	3	75 00	37
Crappie: Overlimit	1	12 00	
Crustaceans: Fail to show on demand	1	10 00	
Diver net: No buoys	1	25 00	
Fail to apply for Fish and Game plates to replace lost ones	1		
Fail to keep fish records	4	35 00	
Fail to register commercial fish boat	2		
Frogs: Taking undersized	3	100 00	
Gill net with meshes over 1¾ inches in length, in District 2, in tidewater in Klamath River, use to take flying fish	8	250 00	25
Lobsters: Possession closed season and undersized	11	125 00	20
Minnows: Use illegal net, seine over 6 ft. long, in District 2, using for bait	5	65 00	
Net: Operate in closed area	1	100 00	
Operate party boat, no permit	1	10 00	
Paranzella net: Operate inside of three mile limit	6	800 00	
Pollution	22	3,650 00	25
Salmon: No license, possession overlimit, take within 250 ft. of the lower side of dam, overlimit in District 11	6	115 00	
Set lines	5	175 00	
Steelhead: No license	1	5 00	
Sunfish: Bluegill, no license	4	50 00	
Trout: Using two rods to take trout, taking trout within 300 feet of the mouth of a stream, possess overlimit, taking trout with more than two attractors	44	708 50	5
Tuna: Undersized yellowfin tuna, selling, no commercial license, take bluefin tuna with purse seine nets	36	1,735 00	180
Yellowtail: On boat carrying round haul net	10		
Totals	572	$13,200 50	792

GAME CASES

July, August, September, 1941

Offense	Number arrests	Fines imposed	Jail sentences (days)
Antelope: Taking and possessing	2	$25 00	
Deer: Take at night, possess doe, closed season, possess female deer, possess deer in refuge, no deer tags, possess spotted fawn, spotlighting, killing doe, fail to have deer tag validated, evidence of sex removed from hide	197	7,285 46	1,087
Deer meat: Closed season	36	1,545 00	460
Doves: Closed season, no license	40	889 50	4
Ducks: Closed season	5	245 00	
Firearms in refuge	41	910 00	
Gallinules: Closed season	1	25 00	
Geese: Closed season	2	50 00	
Hunting: No license, at night, with artificial light, false statement to secure license, in refuge	50	1,033 00	53
Mudhens: Closed season	1	50 00	
Non-game birds, possession	1	10 00	
Pheasant: Closed season, no license	66	3,085 00	85
Pigeons: Closed season	1		
Quail: Closed season	11	475 00	
Rabbits: Taking brush rabbits, closed season, cottontails, closed season, possession jackrabbits, no license	62	893 50	37½
Sagehen: Possession, closed season	5	75 00	25
Shoot from highway, from auto	8	115 00	25
Totals	529	$16,711 46	1,776

SEIZURES OF FISH AND GAME

July, August, and September, 1941

Fish:	
Abalones, pink	56
Abalones, red	7
Albacore, pounds	300
Barracuda	44
Bass	9
Bass, black	34
Bass, striped	164
Bluegill, pounds	6
Carp	1
Clams, cockle	620
Clams, Pismo	266
Corbina	7
Crabs	6
Crappie	7
Frogs	14
Lobster traps	5
Lobsters	125
Perch	8
Salmon	26
Skipjack, pounds	19,182
Sunfish	31
Sunfish, bluegill	94
Sunfish, bluegill, pounds	6
Trout	117
Trout, rainbow	305
Tuna, bluefin, pounds	3,000
Tuna, yellowfin, pounds	240,410
Game:	
Antelope, pounds	80
Bear head	1
Bear hide	1
Deer	5
Deer head	1
Deer hide	1
Deer meat, pounds	3,736
Doves	258
Ducks	40
Geese	2
Meadowlarks	2
Mudhens	2
Pheasants	72
Quail	24
Rail	1
Rabbits	1
Rabbits, brush	9
Rabbits, cottontail	69
Rabbits, jack	2
Robins	3
Sagehen	12
Yellowlegs	1

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In the Service of Their Country

Now serving with the armed forces of the United States are the following 26 employees of the California Division of Fish and Game. Byron Sylvester was killed while on active duty.

James F. Ashley	A. E. Johnson
Arthur Barsuglia	William Jolley
Henry Bartol	Albert King
Ralph Beck	Richard Kramer
J. William Cook	E. L. Macaulay
Donald De Spain	Charles McFall
Edward Dolder	George Metcalf
John E. Fitch	Jacob Myers
Paul Gillogley	James Reynolds
John A. Gray, Jr.	Merton Rosen
Lloyd Hume	William Sholes, Jr.
E. R. Hyde	Edson J. Smith
John F. Janssen, Jr.	Rudolph Switzer

BUREAU OF ENGINEERING

JOHN SPENCER, Chief ---------- San Francisco
Clarence Elliger, Assistant Hydraulic Engineer ---------- San Francisco
Byron Wittorff, Assistant ---------- Red Bluff
Samuel Kabakov, Civil Engineering Draftsman ---------- San Francisco

BUREAU OF LICENSES

H. R. DUNBAR, Chief ---------- Sacramento
L. O'Leary, Supervising License Agent ---------- Sacramento
R. Nickerson, Supervising License Agent ---------- Los Angeles
Emil Dorig, License Agent ---------- San Francisco

ACCOUNTS AND DISBURSEMENTS

D. H. BLOOD, Departmental Accounting Officer ---------- Sacramento

BUREAU OF PATROL

E. L. MACAULAY, Chief of Patrol (absent on military leave) ---------- San Francisco
L. F. CHAPPELL, Chief of Patrol ---------- San Francisco

CENTRAL DISTRICT (Headquarters, Sacramento)

C. S. Bauder, Inspector in Charge ---------- Sacramento

Northern Division

A. A. Jordan, Captain ---------- Redding
Jos. H. Sanders, Captain ---------- Sacramento
A. H. Willard, Captain ---------- Nevada City
E. O. Wraith, Captain ---------- Susanville
L. E. Mercer, Warden, Butte County ---------- Chico
Chester Ramsey, Warden, Butte County ---------- Oroville
Taylor London, Warden, Colusa County ---------- Colusa
Albert Sears, Warden, El Dorado County ---------- Placerville
E. C. Vail, Warden, Glenn County ---------- Willows
Jack Sawyer, Warden, Lassen County ---------- Westwood
Don Davison, Warden, Modoc County ---------- Alturas
Earl Hiscox, Warden, Nevada County ---------- Nevada City
Wm. La Marr, Warden, Placer County ---------- Tahoe City
Nelson Poole, Warden, Placer County ---------- Auburn
E. J. Johnson, Warden, Plumas County ---------- Quincy
George Shockley, Warden, Plumas County ---------- Portola
H. S. Vary, Warden, Sacramento County ---------- Sacramento
Eugene Durney, Warden, Sacramento County ---------- Sacramento
Charles Sibeck, Warden, Sacramento County ---------- Sacramento
Earl Caldwell, Warden, Shasta County ---------- Burney
Chas. Love, Warden, Shasta County ---------- Redding
Don Chipman, Warden, Siskiyou County ---------- Dunsmuir
Brice Hammack, Warden, Siskiyou County ---------- Yreka
Louis Olive, Warden, Siskiyou County ---------- Tule Lake
Fred R. Starr, Warden, Siskiyou County ---------- Dorris
R. E. Tutt, Warden, Sierra County ---------- Downieville
J. E. Hughes, Warden, Solano County ---------- Dixon
A. Granstrom, Warden, Sutter County ---------- Yuba City
R. W. Anderson, Warden, Tehama County ---------- Red Bluff
Harold Erwick, Warden, Tehama County ---------- Corning
C. L. Gourley, Warden, Trinity County ---------- Weaverville
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R. A. Tinnin, Warden, Yuba County ---------- Marysville

Southern Division

S. R. Gilloon, Captain ---------- Fresno
John O'Connell, Captain ---------- Stockton
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Wm. Hoppe, Warden, San Joaquin County ---------- Lodi
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Roswell Welch, Warden, Tulare County ---------- Porterville
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COAST DISTRICT (Headquarters, San Francisco)

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Northern Division

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Henry Lencioni, Captain----Santa Rosa
Ray Diamond, Warden, Del Norte County----Crescent City
Walter Gray, Warden, Humboldt County----Garberville
John Hurley, Warden, Humboldt County----Eureka
W. F. Kalliher, Warden, Humboldt County----Fortuna
Laurence Werder, Warden, Humboldt County----Eureka
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R. J. Yates, Warden, Marin County----San Rafael
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F. H. Post, Warden, Monterey County----Salinas
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Lee C. Shea, Warden, San Francisco County----San Francisco
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M. S. Clark, Warden, Santa Clara County----Palo Alto
C. E. Holladay, Warden, Santa Clara County----San Jose
F. J. McDermott, Warden, Santa Cruz County----Santa Cruz

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Erol Greenleaf, Warden, San Bernardino County----Big Bear Lake
Otto Rowland, Warden, San Bernardino County----Victorville

MARINE PATROL

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Lars Weseth, Master, M.V. *N. B. Scofield*	Terminal Island
Walter Engelke, Master, M.V. *Bluefin*	Monterey
Howard V. Shebley, Warden, Cruiser *Bonito*	Newport Harbor
A. Wallen, Assistant Warden, Cruiser *Bonito*	Newport Harbor
Kenneth Webb, Warden, Cruiser *Broadbill*	San Diego
Phillip Westcott, Assistant Warden, Cruiser *Broadbill*	San Diego
Niles Millen, Warden, Cruiser *Perch*	Antioch
Kenneth Hooker, Warden, Cruiser *Quinnat III*	San Francisco
Richard Hardin, Assistant Warden, Cruiser *Quinnat III*	San Francisco
K. Lund, Warden, Cruiser *Rainbow III*	Martinez
G. Whitesell, Assistant Warden, Cruiser *Rainbow III*	Martinez
Otis Wright, Assistant Warden, Launch *Sturgeon*	Monterey
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D. Ward, Assistant Warden, Cruiser *Tuna*	Santa Monica
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Lester Golden, Warden	Arroyo Grande
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Leslie E. Lahr, Warden	Terminal Island
Ralph Miller, Warden	San Francisco
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T. W. Schilling, Warden	Terminal Island
G. R. Smalley, Warden	Richmond
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L. G. Van Vorhis, Warden	Terminal Island
E. L. Walker, Warden	Terminal Island
Frank Felton, Assistant Warden	San Diego

POLLUTION DETAIL

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John A. Maga, Sanitary Engineer	San Francisco
C. L. Towers, Warden	Los Angeles
Don Hall, Warden	Stockton
H. L. Lantis, Warden	Long Beach
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R. L. Schoen, Warden	Terminal Island
Walter R. Krukow, Assistant Warden	Santa Barbara
J. A. Reutgen, Assistant Warden	Vallejo
Clarence Whaley, Assistant Warden	San Diego

CALIFORNIA JUNIOR GAME PATROL

George D. Seymour	San Francisco

MARINE PATROL AND RESEARCH BOATS

Motor Vessel *N. B. Scofield,* Terminal Island
Motor Vessel *Bluefin,* Monterey
Cruiser *Bonito,* Newport Harbor
Cruiser *Broadbill,* San Diego
Cruiser *Perch,* Antioch
Cruiser *Quinnat III,* San Francisco
Cruiser *Rainbow III,* Martinez
Cruiser *Tuna,* Santa Monica
Cruiser *Yellowtail,* Santa Barbara
Launch *Sturgeon,* Monterey

printed in CALIFORNIA STATE PRINTING OFFICE
SACRAMENTO, *1942* GEORGE H. MOORE, STATE PRINTER